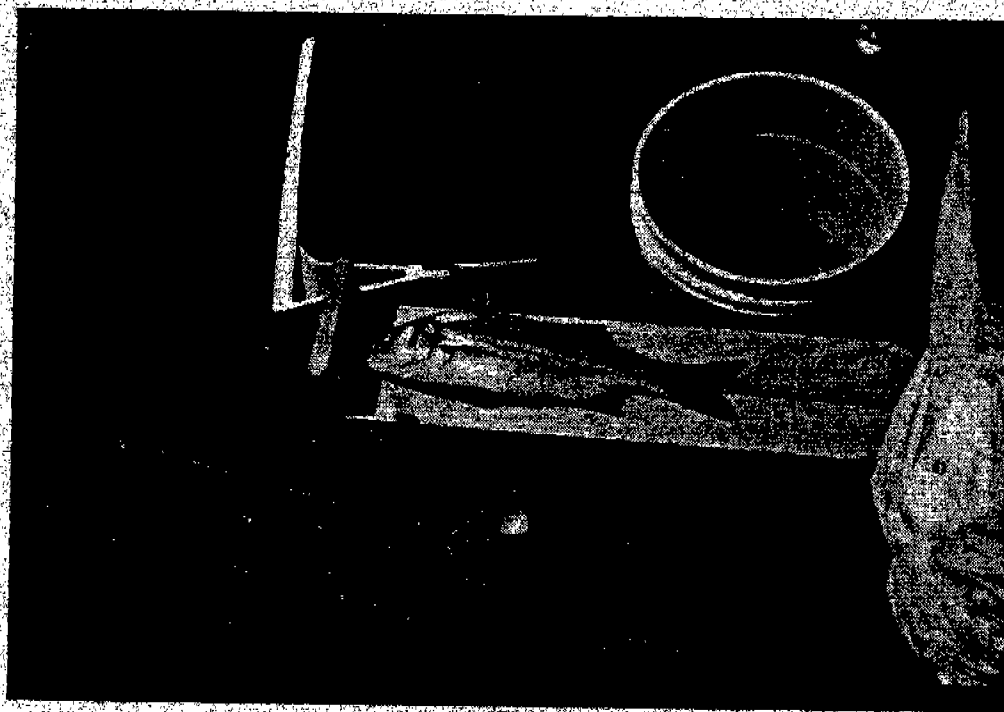




**Final Conceptual Plan**

# **Comprehensive Assessment and Monitoring Program (CAMP)**



*Prepared by:*



**U.S. Fish and Wildlife Service**

**February 1996**



**Comprehensive Assessment and  
Monitoring Program  
(CAMP)  
Final Conceptual Plan**

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## Executive Summary

# Executive Summary

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## INTRODUCTION

The Central Valley Project Improvement Act (CVPIA) (Public Law 102-575, Title 34), enacted in October 1992, provides opportunities to restore anadromous fisheries and wildlife resources in California's Central Valley. Section 3406 is a significant component of CVPIA and proposes comprehensive fish, wildlife, and habitat restoration provisions. Section 3406(b), in particular, directs the Service to develop and implement a series of programs and actions for fish and wildlife purposes, primarily to ensure that by 2002 natural production of anadromous fish in Central Valley streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during 1967-1991. A comprehensive assessment and monitoring program is required to verify that CVPIA Section 3406(b) objectives are met.

CVPIA Section 3406(b)(16) provides the necessary assessment program by directing the U.S. Fish and Wildlife Service (Service) to establish, in cooperation with independent entities and the State of California, a comprehensive program to assess fish and wildlife resources in the Central Valley. This program, the Comprehensive Assessment and Monitoring Program (CAMP), focuses on meeting two distinct goals:

- 1) assess the overall (cumulative) effectiveness of actions implemented pursuant to CVPIA Section 3406(b) by monitoring biological results and
- 2) assess the relative effectiveness of categories of 3406(b) actions toward meeting Section 3406(b) biological goals.

Section 3406(b) actions have been grouped by the Service into the following four major categories to facilitate their evaluation in meeting CAMP's second goal:

- water management modifications,
- structural modifications,
- habitat restoration, and
- fish screens.

A fifth category, waterfowl habitat creation, is covered briefly in Appendix A.

CAMP is being conducted in two phases: Phase I develops this Conceptual Plan, and Phase II develops an Implementation Plan based on the Conceptual Plan. The Conceptual Plan provides a sound basis for the more detailed Implementation Plan and also serves as a road map to help ensure that CAMP objectives are met. CAMP is designed to be broad in scope and evaluate the general or

systemwide results of CVPIA rather than performance of specific actions. Performance measures of specific provisions (actions) are the responsibility of multi-agency teams that will be developed to implement each action. Such action-specific monitoring programs are being designed for the short term (2-5 years) but will provide critical input to CAMP, which is long term (more than 5 years). CAMP will depend largely on the monitoring efforts of the Anadromous Fish Restoration Program (AFRP), the Service, Interagency Ecological Program (IEP), U.S. Bureau of Reclamation, and California Department of Fish and Game (DFG) to meet its goals.

## **CAMP METHODS, ASSUMPTIONS, AND MEASUREMENT PARAMETERS**

Information needed for developing CAMP was obtained from a variety of sources. Initially, available agency documents provided background information on existing and proposed monitoring programs and agency activities throughout the Central Valley. In addition, two workshops were held with key Service, DFG, and IEP staff to increase agency understanding of CAMP goals and receive input on CAMP's direction and measurement parameters. Finally, federal, state, water district, and consulting fisheries biologists were surveyed to identify existing monitoring programs that could provide input to CAMP. The surveys culminated in the development of a monitoring program database that can be used by CAMP staff, as well as by other agencies with monitoring responsibilities.

Several assumptions developed by the Service's Central Valley Fish and Wildlife Restoration Program Office were used in developing CAMP's Conceptual Plan:

- CAMP relies heavily on other monitoring programs for data,
- CAMP will not normally fund basic research,
- CAMP does not employ rigorous statistical methods,
- CAMP does not evaluate the basis for AFRP population goals, and
- CAMP only evaluates 3406(b) effectiveness (and not other CVPIA or non-CVPIA actions).

General measurement parameters were developed for directing CAMP's initial efforts. A watershed-specific approach was selected for evaluating long-term population trends and evaluating action category effectiveness. Target species selected for meeting CAMP's Goal #1 were Sacramento fall-run chinook salmon, Sacramento late fall-run chinook salmon, Sacramento winter-run chinook salmon, Sacramento spring-run chinook salmon, San Joaquin fall-run chinook salmon, Central Valley winter steelhead, striped bass, American shad, white sturgeon, and green sturgeon.

Target life stages for all species are adults except for American shad for which an index of juvenile production is used. To meet CAMP's Goal #1, only these life stages need to be monitored.

Monitoring numbers of juvenile fish is necessary, however, to evaluate the four action categories (Goal #2).

## **MONITORING METHODS AND NEEDS**

Monitoring methods and needs are described separately for meeting CAMP Goal #1 (Chapter 3) and Goal #2 (Chapter 4). The focus of each of these two goals differs sufficiently that monitoring methods and needs, while overlapping, are quite distinct. Both of these chapters provides the foundation for developing the conceptual monitoring program in Chapter 5, but are too detailed to cover extensively herein.

Monitoring methods and needs presented in Chapter 3 for meeting CAMP Goal #1 include species-specific descriptions of CVPIA population monitoring goals, population assessment methods used in the 1967-1991 baseline period, potential revisions to these existing methods, and any possible new methods. Conceptual planning for this goal generally involves ensuring that appropriate long-term population monitoring compatible with 1967-1991 methods and focused on providing long-term abundance estimates comparable to AFRP's restoration goals is in place.

Monitoring methods and needs presented in Chapter 4 for meeting CAMP Goal #2 are much more complex and include descriptions of action categories; target species, races, and life stages; sampling design considerations; and general suggestions. Not every species identified for Goal #1 maintains desirable characteristics for evaluating the effectiveness of action categories. Consequently, only fall-run chinook salmon, winter-run chinook salmon, spring-run chinook salmon, and striped bass were selected for evaluating the effectiveness of the four action categories. These species provide opportunities to assess the effects of the action categories in tributaries (fall- and spring-run chinook salmon), the mainstem Sacramento River (fall- and winter-run chinook salmon), and the Delta (primarily fall-run chinook salmon and striped bass). Striped bass are highly dependent on the estuary for successful production and this is the only species that can be used as a "control" for actions affecting the Delta; all other species will be significantly affected by several categories of actions in the mainstem Sacramento River and its tributaries.

## **CONCEPTUAL MONITORING PROGRAM**

Several levels of alternative conceptual monitoring programs for meeting CAMP Goal #1, and general considerations and guidelines for meeting CAMP Goal #2, are described separately in Chapter 5, the key chapter of the Conceptual Plan. This chapter builds on the goals, concepts, guidelines, monitoring programs, and constraints identified for CAMP in Chapters 1-4. The conceptual monitoring program is intended to provide general conceptual frameworks from which the specific elements of individual monitoring programs can be developed, defined, prioritized, and redefined by the Service. The program for CAMP Goal #2 is much less specific than for CAMP Goal #1 because of uncertainty concerning many of the details of the specific AFRP actions and monitoring programs, which are themselves somewhat conceptual at this time.

The conceptual monitoring program will need to be dynamic, flexible, adaptable, and opportunistic as it is further developed into CAMP's Implementation Plan. AFRP's short-term monitoring programs over the next 10 years will be rapidly designed and deployed. The information generated from these action-specific and other short-term monitoring programs could change several times in the next 10 years to respond to the short-term programs at hand but then stabilize into a consistent, rather than opportunistic, assessment program for the remaining years. It is important to emphasize that CAMP will not influence the priority or scheduling of any restoration actions. Restoration actions will be implemented based on priority needs, funding availability, permit acquisition, and completion of any required environmental documents. CAMP will be "adaptive monitoring" and will not influence restoration action implementation.

### **Program for Assessing Overall Effectiveness of Actions in Doubling Populations (CAMP Goal #1)**

Recommended, high-level, and low-level conceptual monitoring programs are presented for each anadromous species to meet Goal #1. The recommended programs provide the necessary long-term monitoring data to reasonably meet CAMP's Goal #1. The high-level programs include additional or alternative designs and methods that are not considered critical, but would improve the scientific or analytical basis for meeting this CAMP goal. The low-level programs are not recommended because of reductions in the resulting accuracy and precision of subsequent population estimates. This Executive Summary presents only the recommended programs for each species, which are summarized below:

The species-specific programs must be sufficient to monitor populations on a "long-term" basis. AFRP specifies that long term, in this context, must encompass at least several generations of fish (not less than five) over a variety of hydrologic conditions (to allow for natural variation in production) and will continue indefinitely. Based on this guidance, CAMP proposes that monitoring continue for 25-50 years after all Section 3406(b) restoration actions are implemented or until it is determined that sustainable natural production of natural fish of not less than twice the average levels during 1967-1991 has been achieved. The doubling goals, if they are to be attained, will likely be attained within this time frame for chinook salmon, steelhead trout, striped bass, and American shad. An implicit assumption here is that it may take 25 years to increase populations to doubling goals, and then another 25 years to *average* doubling goals on a long-term basis. Programs for white sturgeon and green sturgeon are recommended for 50-100 years, or longer, because of their longevity.

It is envisioned that basic data analysis will occur on an annual basis to identify emerging trends with target populations. More intensive data analyses will occur periodically (every 5 years). After review of these analyses by a designated committee of experts, recommendations will be made concerning adjustments to the program.

## Chinook Salmon

Restoration goals for adult chinook salmon have been established for each of the four races. Additionally, restoration goals have been established for adult fall-run chinook salmon in every river where this race is found. The recommended program is to:

- continue the use of the Schaefer method for estimating annual spawning escapement in the (Feather River, Yuba River, American River, Battle Creek, Mill Creek, Deer Creek, Butte Creek, Tuolumne River, Stanislaus River, Merced River, and Mokelumne River);
- continue annual counts of adult returns to all Central Valley salmon and steelhead hatcheries;
- develop or intensify alternative population estimation procedures to estimate upper Sacramento River chinook salmon runs, including electronic technology (hydroacoustics) and mark-recapture techniques in conjunction with angler surveys;
- continue and expand annual angler survey programs to include all reaches and streams where significant sport fisheries exist;
- continue the annual ocean commercial and sport fishery sampling program; and
- develop a coordinated chinook salmon constant fractional marking program at appropriate Central Valley salmon hatcheries.

Elements of this program that are currently unmet (require additional funding to implement) include some of the river-specific spawning escapement estimates, which are not conducted every year; funds have been cut in recent years, and annual funding can be quite variable. Continued funding of annual spawning escapement surveys in the 11 streams is important to meet CAMP's two goals. Prioritizing streams, using index streams or reaches, or sampling less frequently are all techniques that are discussed in Chapter 5 as alternatives if funding is inadequate. Additional unmet needs include developing or intensifying alternative population estimation procedures to estimate upper Sacramento River chinook salmon runs, continuing and expanding angler survey programs to include all reaches and streams where significant sport fisheries exist, and developing a coordinated chinook salmon marking program at appropriate Central Valley salmon hatcheries. These programs meet some of the basic CAMP needs for effectively monitoring natural production of chinook salmon and also provide basic needs for many other programs and agencies.

## Steelhead Trout

The steelhead restoration goal is established for adult steelhead passing RBDD. The recommended program is to:

- continue adult counts on Mill and Deer creeks,

- continue adult counts at Coleman National Fish Hatchery,
- develop a comprehensive angler survey program on the Sacramento River to accurately and precisely estimate angler harvest to generate estimates of adult steelhead passing RBDD,
- continue to calculate the number of hatchery-produced steelhead that spawned naturally as 29% of the total natural escapement and sportfishing harvest, and
- develop a coordinated steelhead constant fractional marking program at appropriate Central Valley hatcheries.

The elements of this program that are currently unmet and are considered critical to obtain acceptable steelhead population estimates, are the angler survey program on the Sacramento River and the steelhead marking program. Not only has funding for the angler survey program been eliminated for 1996, but the need for this element is even greater because only partial steelhead counts at RBDD are available now and will be available in the future. Because of several problems with the existing relationship between annual steelhead populations passing RBDD and steelhead harvest (see Chapter 3 for details), additional data analyses will be required to develop a new relationship between harvest and steelhead abundance passing RBDD.

### **Striped Bass**

The striped bass restoration goal targets adult populations in the Delta. The recommended program is to:

- continue the existing mark-recapture program for adult striped bass and
- continue current calculation of adult population estimates.

DFG funding for continuing the existing mark-recapture program past June 30, 1996 has been eliminated. Continued funding of the existing striped bass mark-recapture program is considered to be of high priority because there is no other program in place that will collect similar data. The need to continue this sampling program is even more imperative as striped bass has been selected as an indicator species for meeting CAMP's second goal of evaluating the long-term effectiveness of the four action categories in the Delta.

### **American Shad**

The American shad restoration goal is measured as a juvenile midwater trawl (MWT) abundance index in the Delta. The recommended program is to:

- continue the fall MWT surveys consistent with the 1967-1991 period and
- calculate the juvenile shad MWT abundance index annually.

DFG funding for continuing the existing fall MWT surveys is expected in 1996 because of the need to sample Delta smelt. Continued funding of the fall MWT surveys is considered to be of high priority because there is no other program in place that will collect similar data.

### **White Sturgeon and Green Sturgeon**

The white sturgeon restoration goal targets adults in the Delta, and the green sturgeon restoration goal is a percentage of the white sturgeon goal (i.e., it is not an independent goal). The recommended program is to:

- continue the existing mark-recapture program for adult white sturgeon;
- estimate abundance, catch, and natural production estimates for age 15 white sturgeon as currently calculated; and
- estimate the adult population of green sturgeon as currently calculated.

DFG funding for continuing the sturgeon mark-recapture sampling past June 30, 1996 has been eliminated. Continued funding of the mark-recapture sampling program is of high priority because there is no other program in place that will collect similar data. The sturgeon and striped bass sampling programs should be implemented in an integrated fashion, as they have been in the past, to facilitate the most optimal allocation of funding and staff resources.

### **Program for Assessing Effectiveness of Action Categories in Doubling Populations (CAMP #2)**

Evaluating the effectiveness of the four action categories (water management modifications, structural modifications, habitat restoration, and fish screens) in meeting Section 3406(b) doubling goals begins to address the question of *why* anadromous populations have been doubled or not doubled on a long-term basis. This is a much more difficult goal to meet, and only four species/races have been selected to address this goal: fall-run chinook salmon, winter-run chinook salmon, spring-run chinook salmon, and striped bass.

The duration of the monitoring programs required for determining long-term population trends has been established for Goal #1 as 25-50 years for chinook salmon and striped bass. Most action- and site-specific AFRP actions, however, will be monitored over a much shorter time frame (2-5 years). The effectiveness of many actions can be measured within this time frame in relatively simple terms (the presence of adults on restored spawning gravels or increased juvenile survival at a fish screen). An extended period is necessary, however, to evaluate how the chinook salmon and striped bass populations respond to a collective group of actions; simply providing restored gravel may be effective in terms of adding spawning habitat but the actual population response is the criterion that will be measured against the populations goals. Because of high natural variability in anadromous fish populations and the length of time typically needed to measure a population response, such evaluations

will generally require an extended monitoring period to adequately assess population response to various restoration action categories. Continuing adult population estimates for a 25- to 50-year period, and developing juvenile population estimates for approximately a 10-year period in several key watersheds will provide the basis for integrating the short-term monitoring results and evaluating the effectiveness of action categories in key watersheds.

The lack of clear distinction between the effects of the action categories, temporal and spatial overlap between the categories, and high natural (background) variability makes assessing the relative effectiveness of the categories extremely difficult. The desire to immediately implement as many of the provisions as possible to quickly restore fish populations, and the reality that implementation of provisions in various watersheds will be opportunistic and subject to funding availability, prevents or impairs development of a scientific design and implementation schedule that would best facilitate evaluating the relative effectiveness of each action category. Numerous biological, physical, and process-related factors, described in Chapter 5, present constraints to developing specific monitoring designs to meet Goal #2.

General monitoring considerations and guidelines were developed for the four action categories for chinook salmon and striped bass. Only the monitoring guidelines are presented below. Additional detail, such as was presented for meeting Goal #1, cannot be effectively developed until further information is available regarding what specific actions and short-term monitoring programs will be implemented, where they will be implemented, how they will be implemented, and when they will be implemented.

### **Chinook Salmon**

General monitoring guidelines relevant to each of the action categories in restoring chinook salmon populations are as follows:

- select streams or reaches where each action category will be most isolated from the other action categories;
- select streams or reaches where baseline estimates of spawner abundance can be used to evaluate future trends in adult abundance;
- select streams or reaches where overall juvenile production can be accurately estimated and where downstream migrant trapping programs already exist or are being planned;
- select streams or reaches where sequential monitoring of the effects of action categories is possible to temporally isolate action categories;
- if adequate baseline data on juvenile production are not available, conduct outmigrant trapping until restoration actions within each category are implemented;

- where estimating juvenile production is impractical, conduct mark-recapture experiments using "treatment" and "control" groups of marked juveniles to estimate survival of downstream migrants; and
- monitor juvenile production for at least two life cycles (10 years) and adult production for at least five life cycles (25 years) on target watersheds.

For water management actions, streams or reaches should also be selected where daily flow and water temperature data exist and will continue to be measured in the future.

### **Striped Bass**

General monitoring guidelines relevant to each of the action categories in restoring striped bass populations are as follows:

- continue summer tow net, and fall MWT surveys consistent with the 1967-1991 baseline period;
- collect and conduct rigorous analyses of striped bass , young-of-year, juvenile, and adult distribution and abundance data with respect to each action category;
- continue long-term juvenile and adult abundance indices and the monitoring that provides necessary data for those indices;
- continue daily monitoring of Delta hydrodynamic conditions and overall hydrologic regimes of rivers flowing into the Delta;
- conduct site-specific monitoring at locations where actions will be implemented, including both pre- and post-treatment data collection;
- monitor juvenile production for at least two life cycles (10 years) and adult production for at least five life cycles (25 years).

## **DATA MANAGEMENT AND DATA ACCESS PROGRAM**

For CAMP to be successful, it will be necessary to continuously compile and analyze existing and new data on target watersheds and fish populations. Such an effort will require access and some input to the format and management of information to be used to address CAMP goals and objectives. Information needed will come from a variety of sources, formats, governmental agencies, and private entities. A conceptual-level data management and data access program is proposed in Chapter 6 for CAMP to: 1) ensure needed monitoring data are efficiently and properly archived and available and 2) provide a database management system that has the tools needed by CAMP staff to download, review, analyze, and present data. The first goal requires a data repository or data "warehouse", and

the second goal requires a data "mart" that provides the necessary tools (i.e., software capabilities) to readily access available data.

## **RECOMMENDATIONS FOR PHASE II IMPLEMENTATION PLAN**

The Implementation Plan bridges the gap between the Conceptual Plan and a working, implemented, and long-term comprehensive assessment program. Executing CAMP's Conceptual Plan requires refining recommended programs for monitoring methods and timing; identifying specific index watersheds or river reaches for chinook salmon monitoring; prescribing detailed species- and watershed-specific monitoring actions; coordinating data collection, storage, evaluation, and retrieval; producing reports; and evaluating budget needs and funding availability. The structure of the Implementation Plan also will need to accommodate future modifications and respond to monitoring opportunities as information is obtained during the initial CAMP monitoring efforts; environmental conditions change; or CVPIA policies, priorities, or funding change.

Chapter 7 provides many recommendations, too numerous to report here, for the contents of the Phase II Implementation Plan. Reporting requirements also are discussed.



# Introduction

# **Chapter 1. Introduction**

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## **BACKGROUND AND OBJECTIVES**

The Central Valley Project (CVP) provides water service to much of California's Central Valley and affects major anadromous fisheries and wildlife resources throughout most of California. Water storage and release patterns from 20 CVP reservoirs with a combined storage capacity of approximately 11 million acre-feet; flow changes from eight power plants; and approximately 500 miles of major canals, tunnels, and aqueducts have adversely affected substantial fish and wildlife resources and contributed to dramatic declines in certain fish and wildlife populations from historical levels. Despite these adverse effects, CVP facilities offer tremendous opportunities to restore fish and wildlife populations and their associated habitats in numerous major California waterways.

### **Central Valley Project Improvement Act**

The Central Valley Project Improvement Act (CVPIA) (Public Law 102-575, Title 34), enacted in October 1992, recognizes these opportunities and amends the authorization of the U.S. Bureau of Reclamation's (Reclamation's) CVP to include fish and wildlife protection, restoration, and mitigation as project purposes having equal priority with other CVP purposes, such as navigation, flood control, irrigation, municipal water supply, and power generation. The CVPIA's emphasis on fisheries is embodied in four of its six primary purposes:

- protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River Basins of California;
- address impacts of the CVP on fish, wildlife, and associated habitats;
- contribute to California's interim and long-term efforts to protect the San Francisco Bay/Sacramento-San Joaquin Delta estuary; and
- achieve a reasonable balance among competing demands for CVP water, including the requirements of fish and wildlife, agricultural, municipal, industrial, and power contractors.

Section 3406 is a significant component of CVPIA and proposes comprehensive fish, wildlife, and habitat restoration provisions. Section 3406(b), in particular, directs the U.S. Fish and Wildlife Service (Service) to develop and implement a series of programs and actions for fish and wildlife purposes, primarily to ensure that by 2002 natural production of anadromous fish in Central Valley

streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during 1967-1991. A comprehensive monitoring program is required to verify that CVPIA Section 3406(b) objectives are met.

### **CAMP Objectives**

CVPIA Section 3406(b)(16) provides the necessary assessment program by directing the Service to establish, in cooperation with independent entities and the State of California, a comprehensive program to assess fish and wildlife resources in the Central Valley to assess the biological results and effectiveness of actions implemented pursuant to the subsection. This program, the Comprehensive Assessment and Monitoring Program (CAMP), focuses on meeting two primary but distinct objectives:

- 1) assess the overall (cumulative) effectiveness of actions implemented pursuant to CVPIA Section 3406(b) by monitoring biological results and
- 2) assess the relative effectiveness of categories of 3406(b) actions toward meeting Section 3406(b) biological goals.

Goal #1 addresses the specific language in Section 3406(b)(16) to "assess the biological results". Goal #2 addresses the specific language in Section 3406 (b)(16) to assess "the effectiveness of actions". Section 3406(b) actions have been grouped by the Service into the following four major categories to facilitate their evaluation in meeting CAMP's second goal:

- water management modifications,
- structural modifications,
- habitat restoration, and
- fish screens.

A fifth category, waterfowl habitat creation (Section 3406[b][22]), is covered briefly in Appendix A, and is not considered further in the main text of this Conceptual Plan, which addresses only anadromous fish.

### **CAMP Success Criteria**

The basic success criterion for CAMP is to ensure that appropriate population monitoring is in place to determine whether anadromous fish populations are doubled on a sustainable long-term basis.

A second success criterion for CAMP is to ensure that an effective process/program is in place to reasonably determine the relative effectiveness of each of the four action categories in restoring

anadromous fish populations. The ability to isolate and identify the relative effectiveness of the four action categories will be a difficult task. Nonetheless, there are numerous monitoring programs proposed to evaluate Central Valley anadromous fish populations and habitats that CAMP can use to draw reasonable conclusions about the general effects of the four action categories.

## **CAMP Conceptual Plan**

CAMP is being conducted in two phases: Phase I develops this Conceptual Plan, and Phase II develops an Implementation Plan based on the Conceptual Plan. The Conceptual Plan provides a sound basis for the more detailed Implementation Plan and also serves as a road map to help ensure that CAMP objectives are met. The Service has adopted a conceptual approach for evaluating the overall success of the many programs being implemented under Section 3406(b). A key aspect of this approach is that CAMP is designed to be broad in scope and evaluate the general or systemwide results of CVPIA rather than performance of specific actions. Performance measures of specific provisions (actions) are the responsibility of multi-agency teams that will be developed to implement each action. Such action-specific monitoring programs are being designed for the short term (2-5 years), but will provide critical input to CAMP, which is long term (more than 5 years).

Funds do not exist in CAMP to perform action-specific monitoring. By working with the Anadromous Fish Restoration Program (AFRP), however, action-specific monitoring can be conducted by those biologists responsible for implementing the actions. CAMP only provides the broader context by ensuring that these action-specific evaluations provide the necessary information to meet CAMP's broader goals. The Service believes CAMP's broader approach makes better use of existing staff and programs, is more economical, and integrates AFRP responsibilities for action-specific implementation and effective followup monitoring.

A significant focus of CAMP will be on stock-size assessments, which form the bases of the recovery targets of CVPIA. CAMP will meet its first goal by ensuring that appropriate systemwide population estimates are available on a long-term basis for comparison with the doubling goals established by the AFRP (Section 3406(b)(1)).

CAMP can achieve its second goal by focusing on watersheds or stream reaches where individual categories of actions can be evaluated in meeting Section 3406(b) goals. To ensure collection of cost-effective information, CAMP will not attempt to assess success measures on all tributaries on which 3406(b) actions will occur. Instead, selected representative tributaries or stream reaches will be targeted for inclusion in CAMP. CAMP will need to measure success in selected representative watersheds and stream reaches because not all tributaries for each key species or category of actions can be effectively assessed with the funding resources available.

Detailed budget and funding requirements of the program will be explored in CAMP's Implementation Plan. Budget and funding issues were not a focus of this Conceptual Plan and are more realistically covered in Phase II when specific program elements are being proposed for implementation.

Many other actions that may have an impact on fish populations (e.g., fishing regulations, poaching, and predation by sea mammals) are not directly measured by CAMP. Analysis of these actions is beyond the scope of CAMP, which evaluates the relative effectiveness of 3406(b) actions only.

## CONCEPTUAL PLAN ORGANIZATION

The CAMP Conceptual Plan is organized into nine chapters and four appendices as follows:

- Chapter 1, "Introduction",
- Chapter 2, "CAMP Methods, Assumptions, and Measurement Parameters",
- Chapter 3, "Monitoring Methods and Needs for Assessing Overall Effectiveness of Actions in Doubling Populations (CAMP Goal #1)",
- Chapter 4, "Monitoring Methods and Needs for Assessing Effectiveness of Action Categories in Doubling Populations (CAMP Goal #2)",
- Chapter 5, "Conceptual Monitoring Program",
- Chapter 6, "Data Management and Data Access Program",
- Chapter 7, "Recommendations for Phase II Implementation Plan",
- Chapter 8, "Citations",
- Chapter 9, "Acknowledgments",
- Appendix A, "CAMP Conceptual Plan for Wildlife",
- Appendix B, "Data Collection Procedures for Developing CAMP",
- Appendix C, "Correlation Analyses of Chinook Salmon Escapements by Watershed, 1967-1991", and
- Appendix D, "Existing Monitoring Programs Database" (bound separately).

Chapters 2 through 4 provide the building blocks for developing the Conceptual Monitoring Program presented in Chapter 5. Chapter 2 presents methods, assumptions, and measurement parameters used in developing CAMP. Chapter 3 describes monitoring needs for assessing whether populations are doubled, and Chapter 4 describes monitoring needs for assessing whether the action categories are effective in doubling populations. Chapter 5 is the key chapter, representing alternative

conceptual monitoring programs for each species. Chapter 6 conceptually defines a data management and access program that would provide data accessibility and availability between several programs, particularly Camp and IEP. Chapter 7 provides recommendations for implementing Phase II of CAMP, which moves from the conceptual level of detail found in Phase I to the development of a specific Implementation Plan in Phase II. Chapter 8 provides citations used in developing the Conceptual Plan and Chapter 9 acknowledges contributors to the Conceptual Plan.



## **CAMP Methods, Assumptions, and Measurement Parameters**



## Chapter 2. CAMP Methods, Assumptions, and Measurement Parameters

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### METHODS

Information needed for developing CAMP was obtained from a variety of sources. Initially, agency documents provided background information on existing and proposed monitoring programs and agency activities. In addition, two workshops were held with key staff of the Service, DFG, and IEP to increase agency understanding of CAMP goals and receive input on CAMP's direction and measurement parameters. Finally, federal, state, water district, and consulting fisheries biologists were surveyed to identify existing monitoring programs that could provide input to CAMP. The surveys culminated in the development of a monitoring program database that can be used by CAMP staff, as well as by other agencies with monitoring responsibilities.

Appendix B presents the detailed data collection procedures and results used for developing CAMP, as well as the existing monitoring database sorted by watershed and by species. The detailed information precludes its presentation in the main text, but it provides critical information used in the Conceptual Plan. Ultimately, the database will be used to develop CAMP's detailed Implementation Plan.

In addition to meeting directly with Service and DFG staff, CAMP staff reviewed the AFRP's *Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California* (U.S. Fish and Wildlife Service 1995), *A Scientific Basis for Managing Central Valley Chinook Salmon and Steelhead* (California Department of Fish and Game 1995a), and *Restoring Central Valley Streams: A Plan for Action* (California Department of Fish and Game 1993). AFRP's Working Paper (U.S. Fish and Wildlife Service 1995) is only the culmination of the initial phase of development of an AFRP draft Restoration Plan and provides a technical basis for further AFRP plans and actions. AFRP's draft Restoration Plan will evaluate the implementability and reasonableness of the actions described in the AFRP Working Paper. Based on this information, a list of potential target anadromous fish populations by watershed was developed (Table 2-1). Specific selection of target species and populations is presented in Chapters 3 and 4, depending on which CAMP goal (population monitoring or action category effectiveness) is being addressed.

## RELATIONSHIP TO OTHER MONITORING PROGRAMS

Figure 2-1 shows the relationship of CAMP to other monitoring programs. Essential to CAMP is the need for short-term, site-specific, and action-specific effectiveness monitoring as an integral part of each 3406(b) action. These short-term monitoring programs need not be extensive or elaborate efforts; the duration, cost, and complexity of the monitoring will depend on the action being implemented. Each program, however, must determine whether the measure was effective. The proposed policy of the U.S. Department of the Interior is to ensure that each restoration action undertaken pursuant to CVPIA Section 3406(b) includes a plan to assess its effectiveness. These assessments are to be an integral part of the action itself and funded under the same authority. Both the plan for the assessment and the information derived from the monitoring are to be provided to the Service's CAMP project manager and will provide the basic data for CAMP to analyze and meet its goals.

Currently, many of CAMP's monitoring and assessment needs are met by IEP and other state and federal anadromous fish sampling programs. IEP, comprised of numerous federal and state fish and water management agencies, has broad authority for developing monitoring, special study, and research activities for the Sacramento-San Joaquin Estuary. Recently, IEP has expanded geographically by supporting investigations outside the immediate Bay-Delta (Interagency Ecological Program 1995). IEP will need to respond in the near future to the following actions, which will generate needs for additional monitoring activities:

- CVPIA restoration actions;
- December 15, 1994 Accord Category III restoration measures; and
- integrated and coordinated water, structural, and habitat restoration actions in the Delta necessitating real-time monitoring (Interagency Ecological Program 1995).

CAMP and IEP must be closely integrated to maximize the success of each program, particularly because CAMP must rely largely on IEP for data collection and management activities. Although each program has different goals, the information collected through each program will be extremely valuable to the other. Data must be shared between the two programs, but IEP will function as the lead entity for data management. IEP also has much greater involvement in basic research and special study activities, while CAMP's two goals are more specific and focused. In this context, CAMP can provide additional support and data to IEP. It is important to recognize that CAMP is still at the conceptual stage of development, and IEP is currently undergoing several major changes, including a greater focus on a comprehensive monitoring program for the Bay, Delta, and entire Central Valley. Especially in these early stages of development, both programs must be closely integrated as they move forward into implementation. Because of CAMP's narrower focus on two specific goals, IEP will be called on to incorporate CAMP efforts into its broader monitoring and research agenda.

Table 2-1. Potential Target Populations by Watershed

Geographic Area	Fall-Run Chinook Salmon	Late Fall-Run Chinook Salmon	Spring-Run Chinook Salmon	Winter-Run Chinook Salmon	Central Valley Steelhead	Striped Bass	American Shad	White Sturgeon	Green Sturgeon
Upper Sacramento River <sup>a</sup>	x	x	x	x	x	x	x	x	x
Upper Sacramento River Tributaries:									
Clear Creek	x	x	x		x				
Cow Creek	x				x				
Bear Creek	x				x				
Cottonwood Creek	x	x	x		x				
Battle Creek	x	x	x	x	x				
Paynes Creek	x								
Antelope Creek	x	x	x		x				
Elder Creek	x				x				
Mill Creek	x	x	x		x				
Thomes Creek	x		x		x				
Deer Creek	x	x	x		x				
Stony Creek	x	x							
Big Chico Creek	x	x	x		x				
Butte Creek	x	x	x		x				
Miscellaneous Small Tributaries (28)	x				x				

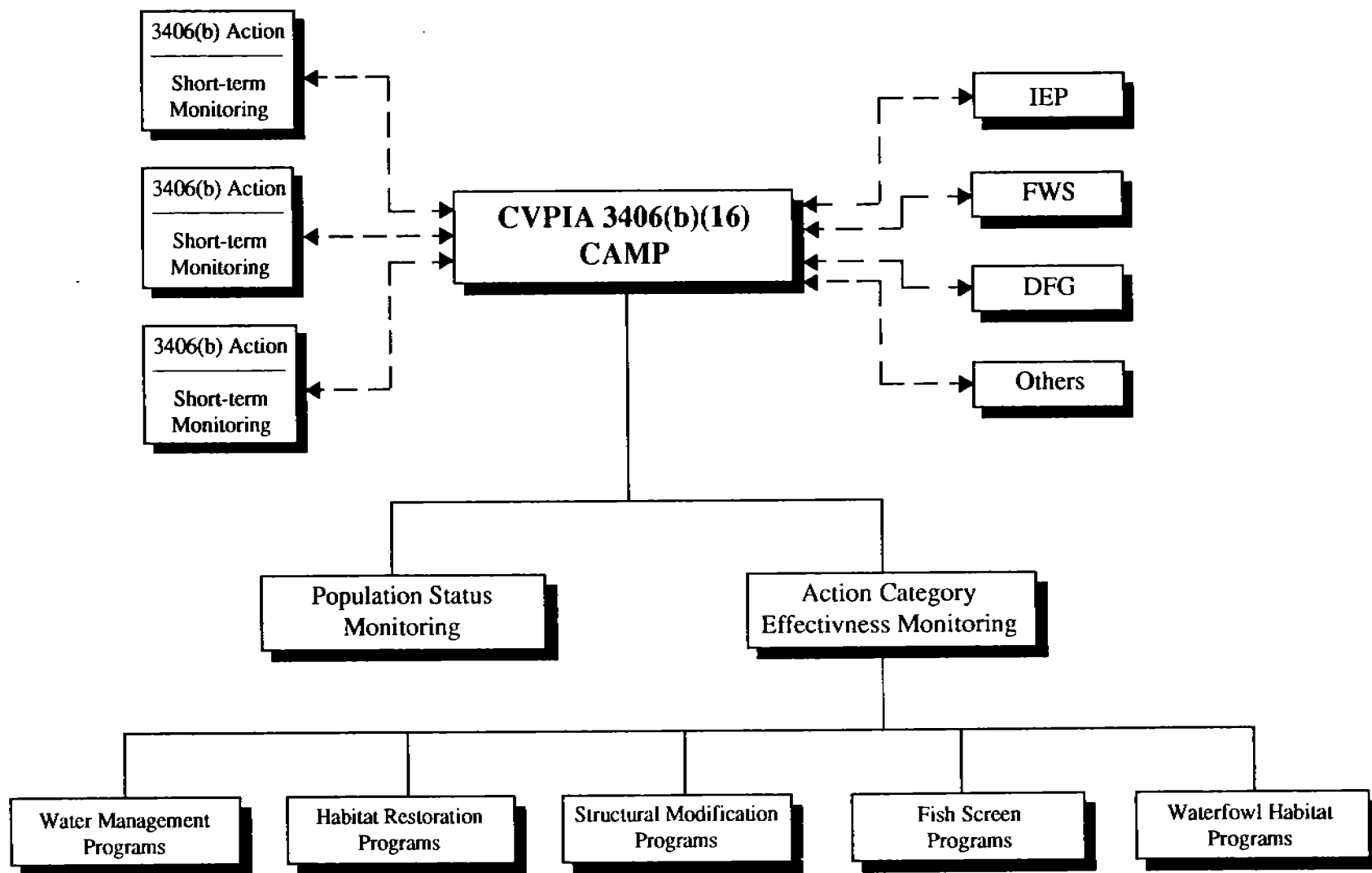
Table 2-1. Continued

Geographic Area	Fall-Run Chinook Salmon	Late Fall-Run Chinook Salmon	Spring-Run Chinook Salmon	Winter-Run Chinook Salmon	Central Valley Steelhead	Striped Bass	American Shad	White Sturgeon	Green Sturgeon
Lower Sacramento River <sup>b</sup>	x	x	x	x	x	x	x	x	x
Lower Sacramento River Tributaries:									
Feather River	x		x		x		x	x	
Yuba River	x				x		x		
Bear River	x				x				
American River	x				x		x		
Mokelumne River	x				x		x		
Consumnes River	x				x				
San Joaquin River and Tributaries:									
Merced River	x								
Tuolumne River	x								
Stanislaus River	x								
Lower San Joaquin River	x					x	x	x	
Calaveras River				x					
Delta	x	x	x	x	x	x	x	x	x

## Notes:

<sup>a</sup> From Red Bluff Diversion Dam upstream to Keswick Dam.<sup>b</sup> Below Red Bluff Diversion Dam.

Table does not include minor or infrequent occurrences of species in watersheds.



**Figure 2-1**  
**Relationship of CAMP to Other Monitoring Programs**

Ongoing Service and DFG monitoring efforts also are extremely important to CAMP. In particular, DFG has been the primary agency responsible for monitoring anadromous fish population trends during the 1967-1991 baseline period. CAMP envisions that the Service and DFG will continue their critical role in population monitoring in the future. CAMP, however, responds to a federal mandate to ensure that these existing and proposed population monitoring programs are conducted in such a manner as to ensure that the cumulative effectiveness of CVPIA actions can be measured with respect to fish population abundance (i.e., to determine if populations are doubled). In this way, CAMP could provide minor funding support for a few of the Service and DFG population monitoring programs that benefit CAMP goals.

Many other ongoing and proposed monitoring programs will provide valuable data that either directly or indirectly will help meet CAMP's long-term goals. A major element in developing CAMP's Conceptual Plan was to identify such programs. These programs will then be included in CAMP's Implementation Plan, as appropriate, as key programs for acquiring data to meet CAMP Goals.

## **COMMON ASSUMPTIONS AND MEASUREMENT PARAMETERS**

CAMP has two distinct goals that each requires its own set of assumptions and measurement parameters; these specific assumptions and parameters are discussed in Chapters 3 and 4. There are certain assumptions and measurement parameters for CAMP, however, that are common for both objectives. Common assumptions, which were developed by the Service's Central Valley Fish and Wildlife Restoration Program Office, and general measurement parameters are described below.

### **Common Assumptions**

#### **CAMP Relies Heavily on Other Monitoring Programs**

A basic and critical assumption is that CAMP will rely heavily on existing and proposed monitoring programs to provide the necessary database to meet its objectives. CAMP has limited funds for conducting its own monitoring efforts and will use what funds it does have to analyze data collected by others, report its long-term findings to the U.S. Department of the Interior and to Congress, and contribute to critical monitoring programs to the extent possible. CAMP will rely primarily on the AFRP 3406(b) action-specific monitoring, IEP monitoring and research, and continued Service and DFG programs for estimating anadromous fish population abundance and the effectiveness of the four action categories. If other monitoring programs are insufficient to meet CAMP needs, CAMP will need to adapt to budget constraints, prioritize recommended programs, and implement programs that can be accomplished within the available budgets.

## **CAMP Will Not Normally Fund Basic Research**

CAMP is focused on evaluating long-term population trends and evaluating the relative effectiveness of the four categories of actions in increasing fish populations. These basic goals can be addressed without baseline research, although such research would provide invaluable information in testing assumptions used in developing population estimates and a better understanding of the factors that limit fish populations. The short-term, action-specific 3406(b) monitoring programs, in addition to IEP research programs, are assumed to provide the necessary information for CAMP. Consequently, this Conceptual Plan does not propose any research programs, but it does identify information needs that would improve the accuracy and precision of population estimates used in CAMP.

## **CAMP Does Not Employ Rigorous Statistical Methods**

CAMP will generally evaluate long-term population trends and assess action category effectiveness in a qualitative manner based on available quantitative data and limited statistical analyses. The Service does not envision the need to employ a rigorous statistical design at this time nor is such a design very practical because restoration actions, as they are implemented, will drive the monitoring design rather than vice versa. Complex statistical designs are not deemed appropriate to meet CAMP's primary goal of comparing future long-term population trends with population goals.

Currently, there is insufficient information on specifically *what* actions will be implemented, *where* they will be implemented, *when* they will be implemented, and *how* they will be monitored to develop a specific sampling design to meet CAMP's second goal of evaluating the success of action categories. It is likely that no sampling design could be developed to reasonably accomplish such a goal because of the extreme variability in numerous, integrated biological and physical factors. Additionally, the Service will be implementing actions as rapidly as possible to meet CVPIA needs, and facilitating optimal sampling designs will not be a factor in how or where the Service implements each factor. The Service desires only to qualitatively determine the relative effectiveness of each action category in meeting population doubling goals. This Conceptual Plan provides a general program for accomplishing this goal. A subsequent Implementation Plan will provide additional detail but will remain flexible to adapt to the restoration priorities, goals, and project-specific implementation schedules of the Service.

## **CAMP Does Not Evaluate the Basis for AFRP Population Goals**

The AFRP developed population (doubling) goals for anadromous fish species and races based on baseline (1967-1991) populations estimates. Although the annual population estimates that form the basis for the AFRP population goals vary in terms of their precision and accuracy, the goals were developed by a coalition of senior fish experts from state and federal agencies, private industry, and academia with specific knowledge of anadromous fish species in Central Valley rivers and streams. The AFRP population goals are the basis on which to compare average long-term population levels. If AFRP population goals are modified in the future, CAMP will make the necessary adjustments in its programs to accommodate AFRP.

## **CAMP Evaluates Only 3406(b) Effectiveness**

CAMP addresses only the long-term effectiveness of 3406(b) actions and does not evaluate other CVPIA or non-CVPIA actions. In this context, CAMP has a much more narrow focus than does IEP.

## **General Measurement Parameters**

Preliminary CAMP measurement parameters were developed by watershed (Table 2-2). These parameters provided guidance for directing CAMP's initial efforts but are defined more specifically relative to CAMP's two goals in later chapters.

## **Watersheds**

CAMP needs encompass the Sacramento and San Joaquin rivers, their major tributaries, and the Delta. A watershed-specific approach is consistent with AFRP and facilitates proper management of Central Valley anadromous fisheries resources. The CAMP Conceptual Plan is based on selecting and sampling appropriate watersheds for monitoring to meet CAMP's goals.

## **Population Parameters**

**Target Species/Races/Populations.** Sacramento fall-, late fall-, winter-, and spring-run chinook salmon; San Joaquin fall-run chinook salmon; and Central Valley winter steelhead are recommended as target salmon and steelhead populations for CAMP. These populations also have been classified as "evolutionarily significant units" (ESUs) by DFG (1995a). A population (or group of populations) is typically considered "distinct" (and hence a species) if it represents an ESU of the biological species. A population must satisfy two criteria to be considered an ESU: 1) it must be reproductively isolated from other conspecific population units, and 2) it must represent an important component in the evolutionary legacy of the species. Isolation does not have to be absolute, but it

must be strong enough to permit evolutionarily important differences to accrue in different population units. The second criterion would be met if the population contributed substantially to the ecological or genetic diversity of the species as a whole.

Striped bass, American shad, white sturgeon, and green sturgeon are proposed to be monitored as single target populations because these populations lack the degree of reproductive isolation exhibited by other species such as chinook salmon and are not known to possess reproductively isolated population units within the Central Valley.

**Target Life Stages.** The adult life stage is the primary target life stage because AFRP doubling goals for CAMP are based on adults, except for American shad. At a minimum, CAMP's target life stages must match the target life stages used by AFRP to establish CVPIA doubling goals. To meet CAMP's first goal of determining whether populations are doubled, only adults and the juvenile shad index need to be enumerated.

Monitoring numbers of juvenile fish is necessary to meet CAMP's second goal of evaluating the effectiveness of the four CAMP action categories (water management, structural changes, habitat improvements, and fish screen installations). Adult populations are subject to too many of the action categories and too broad a range of other factors to assess the effectiveness of individual action categories (most of which directly affect juvenile survival and abundance). In addition, many of the action-specific monitoring programs will be directed at monitoring juveniles because the restoration action itself is directed at increasing juvenile survival rates.

## **Habitat Parameters**

Habitat monitoring parameters are not needed for CAMP to determine whether populations are doubled. However, monitoring of several habitat parameters is essential to effectively evaluate responses of fish populations to certain categories of restoration actions. River flow monitoring, as measured by standard flow gages, is essential to document widely varying natural flow conditions and water management modifications. Water temperature monitoring is essential to ensure that the secondary effects of reservoir operations and downriver flow changes on this key habitat parameter are considered when population responses are evaluated. Water depth, velocity, substrate, and cover are essential habitat parameters that, at least in part, control the production capacity of any watershed. Actions that change these parameters (e.g., flow changes, habitat restoration) generally affect populations indirectly; thus, changes in these parameters could be monitored when long-term changes in population abundance measures are evaluated. Although the link between habitat parameters and fish population abundance is difficult to quantify, habitat monitoring may help evaluate the effectiveness of the CAMP action categories.

Table 2-2. Preliminary CAMP Measurement Parameters by Watershed

Watershed	Species/Races/ Populations	Target Life Stages	Assessment Parameters	Habitat Parameters
Upper Sacramento River	Sacramento winter-run chinook salmon; Sacramento fall-run chinook salmon; Sacramento late fall-run chinook salmon	Juvenile, adult	Ocean and river harvest, adult escapement (RBDD counts, carcass surveys, redd counts etc.), juvenile and smolt abundance indices (screw trap and beach seine catches; diversion counts)	Flow, water temperature, depth, velocity, substrate, and cover
	Central Valley winter steelhead	Juvenile, adult	River harvest, juvenile and smolt beach seine and screw trap abundance indices	Flow, water temperature, depth, velocity, substrate, and cover
Upper Sacramento tributaries	Sacramento fall-run chinook salmon, Sacramento late fall-run chinook salmon, Sacramento spring-run chinook salmon	Juvenile, adult	Ocean and river harvest, adult escapement (carcass surveys, snorkel surveys, RBDD counts, etc.), juvenile and smolt abundance indices (screw trap and beach seine catches; diversion counts)	Flow, water temperature, depth, velocity, substrate, and cover
	Central Valley winter steelhead	Juvenile, adult	River harvest, juvenile and smolt beach seine and screw trap abundance indices	Flow, water temperature, depth, velocity, substrate, and cover
Feather River	Sacramento fall-run chinook salmon, Sacramento spring-run chinook salmon	Juvenile, adult	Ocean and river harvest, adult escapement (spawning surveys, carcass surveys, etc.), fry (screw trap and beach seine catches; diversion counts) and smolt abundance indices	Flow, water temperature, depth, velocity, substrate, and cover
	Central Valley winter steelhead	Juvenile, adult	River harvest, juvenile beach seine and trap catch indices, and smolt abundance indices	Flow, water temperature, depth, velocity, substrate, and cover
Yuba, American, Mokelumne, and Cosumnes rivers	Sacramento fall-run chinook salmon	Juvenile, adult	Ocean and river harvest, adult escapement (ladder counts, carcass surveys, etc.), juvenile and smolt abundance indices (screw trap and beach seine catches; diversion counts)	Flow, water temperature, depth, velocity, substrate, and cover
	Central Valley winter steelhead	Juvenile, adult	River harvest, juvenile and smolt beach seine and screw trap abundance indices	Flow, water temperature, depth, velocity, substrate, and cover
San Joaquin River tributaries (Merced, Stanislaus, and Tuolumne rivers)	San Joaquin fall-run chinook salmon, and Central Valley winter steelhead	Juvenile, adult	Ocean and river harvest, adult escapement (carcass surveys, etc.), juvenile and smolt abundance indices (screw trap and beach seine catches; diversion counts)	Flow, water temperature, depth, velocity, substrate, and cover

Table 2-2. Continued

Watershed	Species/Races/ Populations	Target Life Stages	Assessment Parameters	Habitat Parameters
Calaveras River	Calaveras River winter-run chinook salmon	Juvenile, adult	Ocean and river harvest, adult escapement (carcass surveys), juvenile and smolt abundance indices (screw trap and beach seine catches; diversion counts)	Flow, water temperature, depth, velocity, substrate, and cover
Delta, lower Sacramento River, lower San Joaquin River	Sacramento fall-, late fall-, spring-, and winter-run chinook salmon, Central Valley winter steelhead, San Joaquin fall-run chinook salmon	Juvenile	Sacramento/Chipps trawl catches, San Joaquin/Chipps trawl catches, beach seine catches, Bay trawl catches, marked fish estimates, and smolt abundance indices	Delta inflow and outflow, DCC operation, export/inflow ratio, exports, water temperature
	Striped bass	Juvenile, adult	Summer tow net index, fall midwater trawl index, juvenile and adult mark-recapture population estimates	Delta inflow and outflow, river flows, zooplankton abundance, export/inflow ratio, exports
	American shad	Juvenile	Fall midwater trawl index	Delta outflow, river flows
	White sturgeon and green sturgeon	Juvenile, adult	Juvenile and adult population estimates, full midwater trawl index, tow net index	Delta outflow, river flows

Note: Some species are present in watersheds but not included in this table because they cannot be effectively evaluated in those streams (e.g., white sturgeon in the Feather River), or there are few population data (e.g., white sturgeon in the upper Sacramento River).

**Monitoring Methods and Needs for Assessing Overall  
Effectiveness of Actions in Doubling  
Populations (CAMP Goal #1)**

## **Chapter 3. Monitoring Methods and Needs for Assessing Overall Effectiveness of Actions in Doubling Populations (CAMP Goal #1)**

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### **INTRODUCTION**

This chapter focuses entirely on CAMP's primary objective of assessing the overall (cumulative) effectiveness of actions implemented pursuant to CVPIA Section 3406(b), which is measured to the degree which populations meet the AFRP restoration (i.e., doubling) goals on a long-term, sustainable basis. This chapter provides information that is the foundation for developing much of the Conceptual Plan and seeks to:

- summarize and describe previous methods used for assessing abundance of target populations for the 1967-1991 baseline period,
- present potential revisions to these existing methods,
- offer new methods that may assist in assessing target populations, and
- describe monitoring needs for accurately assessing whether species-specific population goals are met.

Information for preparing this chapter came from meetings with AFRP and IEP staff, as well as from several key publications (particularly Mills and Fisher [1994] and U.S. Fish and Wildlife Service [1995]). Mills and Fisher (1994) was prepared as supportive documentation required for implementing the CVPIA. It provides the basis for the baseline natural production estimates and goals established for the AFRP (U.S. Fish and Wildlife Service 1995). All population goals, methods for determining population goals, and data needs are species-specific, and information is arranged in this chapter by species.

### **POPULATION MONITORING GOALS**

The CVPIA's population monitoring goals by species and race are specified in AFRP's Working Paper (U.S. Fish and Wildlife Service 1995). The monitoring (restoration) goals for anadromous fish were to be equal to or at least twice the mean estimated natural production for the baseline period (1967-1991). Natural production was defined during the baseline period to be that

portion of production not produced in hatcheries and to be the number of fish that recruit to adulthood in a given year, including newly recruited fish that are harvested. The CAMP Project Team did not evaluate the methodology for deriving the AFRP restoration goals and assumes that these goals are the measures by which CAMP can ascertain the long-term effectiveness of CVPIA Section 3406(b) restoration actions. As additional information is developed on population trends and monitoring methods, however, some of the goals could change. CAMP is sufficiently flexible to incorporate any modified goals into its long-term evaluation process.

## **Chinook Salmon**

Table 3-1, excerpted from the AFRP Working Paper, summarizes preliminary estimated restoration goals for chinook salmon based on doubling of natural production. Natural production doubling goals for adult chinook salmon (based on 1967-1991 escapement, instream and ocean harvest, and total and natural production) are as follows:

- all chinook salmon races combined - 990,000,
- fall-run chinook salmon - 750,000,
- late fall-run chinook salmon - 68,000,
- winter-run chinook salmon - 110,000, and
- spring-run chinook salmon - 68,000.

The AFRP Working Paper also defines goals for various watersheds in the Central Valley. CAMP is not be designed to evaluate whether every watershed-specific goal will be met but rather whether overall goals for each of the four chinook salmon races will be met. A subsampling program may be required to determine whether goals are being met in several "indicator" watersheds, but not necessarily every watershed where there is a numeric goal. While monitoring each watershed at a relatively constant level of effort would be preferable, future funding sources will not permit such comprehensive monitoring. Chapter 5, which describes the Conceptual Monitoring Program, provides several alternative sampling approaches that could be implemented, depending on the Service's overall goals, funding capabilities, and priorities.

## **Steelhead Trout**

Insufficient data are available to estimate natural production of steelhead in the Central Valley other than upstream of RBDD. The restoration goal for steelhead spawning upstream of RBDD is 13,000 adult steelhead per year. If steelhead monitoring efforts are intensified through other programs in other watersheds, AFRP may elect to establish additional steelhead restoration goals. In this case, CAMP would adjust its assessment program to evaluate whether these new restoration goals are met over the long term.

Table 3-1. Escapement, Harvest, and Production Data and Preliminary Estimated Restoration Goals for Chinook Salmon Based on Doubling of Natural Production

Race and river <sup>a</sup>	Escapement	Harvest		Production		Goal <sup>b</sup>
		Instream	Ocean	Total	Natural	
All races combined	280,000	53,000	410,000	740,000	500,000	990,000
Fall-run	220,000	40,000	340,000	610,000	370,000	750,000
Late fall-run	15,000	5,500	24,000	34,000	22,000	68,000
Winter-run	23,000	4,600	26,000	54,000	54,000	110,000
Spring-run	13,000	2,400	19,000	34,000	34,000	68,000
Sacramento River						
Fall-run	77,000	7,700	110,000	190,000	120,000	230,000
Late fall-run	14,000	2,800	20,000	37,000	22,000	44,000
Winter-run	23,000	24,000	26,000	54,000	54,000	110,000
Spring-run	11,000	2,200	16,000	29,000	29,000	59,000
Clear Creek	1,600	160	2,700	4,500	3,600	7,100
Cow Creek	1,400	140	1,400	2,900	2,300	4,600
Cottonwood Creek	1,600	160	1,900	3,700	3,000	5,900
Battle Creek						
Fall-run	18,000	1,800	31,000	50,000	5,000	10,000
Late fall-run	1,000	200	1,500	2,700	270	550
Paynes Creek	90	10	110	200	160	330
Antelope Creek	190	20	240	450	360	720
Mill Creek						
Fall-run	1,100	110	1,400	2,600	2,100	4,200
Spring-run	800	80	1,300	2,200	2,200	4,400
Deer Creek						
Fall-run	410	40	510	950	760	1,500
Spring-run	1,300	130	1,800	3,300	3,300	6,500
Miscellaneous creeks	300	30	350	680	550	1,100
Butte Creek						
Fall-run	420	40	490	951	760	1,500
Spring-run	360	40	620	1,000	1,000	2,000
Big Chico Creek	240	20	230	500	400	800
Feather River	49,000	9,700	80,000	140,000	86,000	170,000
Yuba River	13,000	1,300	19,000	33,000	33,000	66,000
Bear River	100	10	110	220	220	450
American River	41,000	18,000	75,000	130,000	81,000	160,000
Mokelumne River	3,300	300	4,100	7,800	4,700	9,300
Cosumnes River	760	80	800	1,600	1,600	3,300
Calaveras River						
Winter-run	410	480	590	1,100	1,100	2,200
Stanislaus River	4,800	240	5,800	11,000	11,000	22,000
Tuolumne River	8,900	450	9,500	19,000	19,000	38,000
Merced River	4,500	230	5,100	9,900	9,000	18,000

Notes:

<sup>a</sup> Data for rivers without a race designation are for fall-run chinook salmon.

<sup>b</sup> Because of rounding errors, goal category numbers do not add up to twice the natural production category numbers.

Source: Excerpted from the Service's AFRP Working Paper (U.S. Fish and Wildlife Service 1995).

## **Striped Bass, American Shad, White Sturgeon, and Green Sturgeon,**

The striped bass goal is 2,500,000 adult fish. The goal for American shad, expressed as a juvenile index as derived from the DFG fall midwater trawl (MWT), is 4,300. The shad goal is only an index and not the actual number of fish desired, which would be higher but indeterminable with existing data. The goals for white sturgeon and green sturgeon are 11,000 and 2,000 adult fish, respectively.

### **RELATIONSHIP OF 1967-1991 METHODS TO CAMP OBJECTIVES**

The methods used to assess abundance of target anadromous species for the 1967-1991 baseline period (Mills and Fisher 1994) and to determine the restoration goals for each of these species (U.S. Fish and Wildlife Service 1995) must be used to assess the overall (cumulative) effect of actions implemented pursuant to CVPIA Section 3406(b). Comparable methods and data are required for meaningful comparisons between pre- and post-CVPIA fish populations. This section summarizes the methods used to assess abundance of target anadromous fish species during the 1967-1991 baseline period and identifies possible revisions or additional methods that would further assist in assessing achievement of restoration doubling goals.

From 1967 to 1991, data collection efforts varied and generally did not focus on estimating levels of natural production; therefore, estimating natural production levels for this period was challenging for most species and drainages. The AFRP, however, using several technical teams and the Mills and Fisher (1994) report as a base document, has developed estimates of natural production and set numeric goals for each species (U.S. Fish and Wildlife Service 1995). This section evaluates how the methods used to develop these goals can be carried forward and possibly improved to ensure that long-term monitoring is conducted in the most accurate and precise manner, yet with comparability and compatibility with 1967-1991 methods.

### **GENERAL POPULATION ASSESSMENT METHODS (1967-1991)**

Population assessment methods used to develop the 1967-1991 population estimates are summarized by Mills and Fisher (1994) and the Service (U.S. Fish and Wildlife Service 1995). The information presented in this section is primarily excerpted from those documents. Sampling methods for American shad, striped bass, white sturgeon, and green sturgeon were obtained from these two publications, as well as from information provided by DFG biologists Dave Kohlhorst and Don Stevens (pers. comms.).

## **In-River Populations**

Common methods used to assess population sizes of Central Valley anadromous fish species include direct counts, mark-recapture methods, indexing abundance, and Central Valley angler surveys.

The direct count method generally involves observing and counting salmon and steelhead as they ascend a fishway or ladder. This method is used in the Central Valley at RBDD in the Sacramento River, Woodbridge Dam on the Mokelumne River, and at hatchery facilities that propagate salmon and steelhead. Variants of the direct count method include the use of video cameras and electronic fish-counting devices to record the passage of adult-sized fish through a fishway or ladder. Direct counts usually involve procedures to account for fish passage when an observer is not present or to calibrate electronic counting devices. Often, direct counts are impaired by high turbidity or flows, which eliminate opportunities to observe fish. Counts for days of no observation are generally accounted for by interpolating from data taken on days surrounding those periods.

Aerial surveys are used in the Sacramento Valley to count chinook salmon redds, particularly in the Sacramento River between Princeton and Keswick. The ratio of redd counts below RBDD to redd counts above RBDD, multiplied by the number of salmon above RBDD (ladder counts), is used to estimate the number of fall-run chinook salmon spawning below RBDD.

Mark-recapture methods include the use of various methods such as Petersen, Schaefer, Schumacher and Eschmeyer, and Jolly-Seber. The Petersen method is a "single census" method in which fish are marked once, and during subsequent recapture efforts the numbers of marked and unmarked fish are recorded. The other methods are the "multiple census" type in which fish are marked and added to the population over a considerable period during which samples are taken and examined for recaptures. In general, mark-recapture methods have similar assumptions about survival of marked fish: no tags will be lost, marked fish will become randomly mixed with the unmarked population, all marks will be recognized and reported, there will be negligible recruitment to the population during the recovery period, and losses (e.g., mortality) of marked and unmarked fish will not differ significantly (i.e., closed population). The Jolly-Seber method differs from these methods in that it is suitable for estimating abundance of open populations in which there is mortality, recruitment, immigration, and emigration. In many instances, it is possible to correct for known violations of these assumptions, such as correcting for tag loss or adjusting for known mortality.

Indexing, a more subjective approach to estimating populations, relies heavily on the experience and knowledge of the observer. This method is most often used in the Central Valley on small tributary streams having chinook salmon spawning populations that are too small to allow mark-recapture methods or that would require intensive efforts to conduct direct counts. By this method, the observer may conduct one or two surveys of the creek (or a portion of the creek) during the spawning season and, based on observations, estimate population abundance in increments of 100 fish. This method is used primarily in streams that support several hundred or fewer fish.

Angler surveys are often used to estimate the harvest of chinook salmon and steelhead within rivers and streams in the Central Valley. Typically, angler surveys methods use a stratified random sampling procedure by which survey areas are predefined and then sampled on a random but structured basis throughout the survey period. Sampling is stratified by location and time. Catch and effort data collected during the structured sampling are expanded to account for days, times, and location where no sampling occurred. Occasionally, angler surveys are conducted in conjunction with mark-recapture studies to gather tag recovery data to estimate population size.

### **Hatchery Counts**

The Service operates Coleman National Fish Hatchery on Battle Creek, an upper Sacramento River tributary, and DFG operates the Feather River, Nimbus (American River), Mokelumne River, and Merced River hatcheries (Table 3-2). Fall-run chinook salmon are propagated at Coleman National Fish Hatchery and all four state-operated hatcheries. Steelhead are propagated at Coleman National Fish Hatchery, and at Feather River, Nimbus, and Mokelumne River hatcheries. Feather River Hatchery also propagates spring-run chinook salmon, and Coleman National Fish Hatchery propagates winter-run and late fall-run chinook salmon.

Hatchery counts represent fish counted during sorting and spawning procedures.

### **Ocean Commercial and Sport Landings**

The ocean commercial salmon fisheries are extensively monitored by DFG to provide estimates of total pounds and numbers of salmon landed at ports along the California coast. Port sampling is conducted using a random subsampling of landed fish, which allows landing data to be expanded to account for periods when no sampling occurs.

Anglers participating in the coastal charter boat and sport skiff fisheries for salmon are censused on their return to port. Not every boat is sampled, but the method allows for extrapolation of data to provide an estimate for total sport harvest.

Ocean landings of all other Central Valley anadromous species (steelhead, striped bass, American shad, white sturgeon, and green sturgeon) are minor, incidental catches and are not monitored.

# CHINOOK SALMON

## Population Assessment Methods

Annual spawning escapement estimates constitute the most complete long-term record of Central Valley chinook salmon populations during the 1967-1991 baseline period. Inland harvest estimates have been sporadic and limited to only some Central Valley rivers and streams. Ocean harvest estimates are available for the entire baseline period but do not provide accurate estimates of the contribution of individual stocks or races, including those from other Pacific Coast basins. Efforts to estimate the proportion of hatchery-produced fish in the spawning escapement have had limited success because of the lack of a consistent marking program or standard method for discriminating naturally produced fish from hatchery-produced fish.

### In-River Populations

**Mark-Recapture Methods.** A modified form of the Schaefer method (Schaefer 1951) has been the primary method used by DFG to estimate in-river chinook salmon spawning populations during the baseline period. This method has been applied routinely to estimate fall-run chinook salmon spawning escapement in several major Central Valley spawning tributaries. Surveys are usually conducted weekly during the principal spawning season. During each survey, field personnel tag fresh carcasses and return them to flowing water for dispersal in the river, chop decomposing carcasses in half, and recover carcasses tagged on previous survey dates. Weekly estimates of adult salmon (age 3 and older) are computed based on the proportion of tagged carcasses of adult size that are recovered relative to the total number of tagged carcasses at large and the total number of carcasses observed (tagged and untagged). Estimates of grilse (predominantly age-2 males) are typically based on the proportion observed during the surveys. Weekly estimates are added to obtain the total spawning escapement estimate for the season.

The Schaefer method has not always been consistently used in rivers for several reasons. In years when high flows or turbidity impair carcass recoveries, total estimates are derived by interpolating or extrapolating data based on the average spawning distribution from past years. Because of fiscal constraints on DFG, which vary annually, the labor-intensive Schaefer method is sometimes applied with different levels of effort (number of surveys, number of biologists on a survey team, number of surveyed reaches) on each target river and even among years on the same river.

The Jolly-Seber method, another mark-recapture technique, has recently been examined as a potential alternative to the Schaefer method (Snider et al. 1993), but it has not been used for any of the individual spawning escapement estimates on which the AFRP's restoration goals are based.

**Direct Counts.** Direct counts of upstream migrating adult chinook salmon have been possible at RBDD since its completion in 1967. Fall-run, late fall-run, winter-run, and spring-run chinook salmon are counted as they ascend the fish ladders on either side of the dam. Because these counts

Table 3-2. Hatchery Propagation by Species

Species	Service	DFG			
	Coleman National	Feather River	Nimbus	Mokelumne River	Merced River
Fall-run chinook salmon	x	x	x	x	x
Late fall-run chinook salmon	x				
Winter-run chinook salmon	x				
Spring-run chinook salmon		x			
Central Valley steelhead trout	x	x	x	x	

\* Hatchery operations for winter-run chinook salmon are on hold for 1996.

do not include fish spawning below the dam, total estimates for fall-run chinook are developed by conducting aerial counts of redds above and below the dam and multiplying this ratio by the number of fish spawning above the dam (based on ladder counts) to estimate the number spawning below the dam. Direct counts involve procedures (e.g., interpolation) to account for fish passage when observations are impaired by high flows, turbidity, or dam operation.

Direct counts also include snorkel surveys to count adult spring-run chinook salmon during their summer residence in deep, cold pools in the upper reaches of some tributary streams. This method of direct count requires intensive efforts by skilled observers to locate and identify fish. Generally, underwater counts are used as a relative measure of fish abundance and not an absolute count.

**Inland Sport Harvest.** Limited harvest information is available to determine inland sport catches of chinook salmon in the Central Valley during the baseline period. Although comprehensive measures of in-river sport harvest have not been made on a consistent basis, sporadic angler surveys have been conducted on some rivers during the baseline period. Typically, angler survey methods use a stratified random sampling procedure in which survey areas and time periods (e.g., weekends) are sampled randomly throughout the survey period. Catch and effort data collected during sampling are expanded to account for locations and times not sampled. One simple approach to estimate annual in-river harvest of chinook salmon was made by Meyer (1985, cited in Mills and Fisher 1994) who assumed the in-river harvest was a constant fraction of the total ocean sport harvest. He applied 10% as a reasonable estimate, combining the various runs. An angler survey conducted in the upper Sacramento River from 1967 through 1975 yielded annual estimates of total in-river harvest (Rowell 1980, cited in Mills and Fisher 1994). A significant relationship between the harvest rate above RBDD and total river harvest rate has been used to estimate total annual harvest in the upper Sacramento River in subsequent years.

Angler surveys conducted from January 1991 through December 1994 were used to estimate angler effort and catch of anadromous species in the Sacramento, American, Feather, and Yuba rivers (Wixom et al. 1995).

**Spawning Index Reaches.** This method is most often used on tributary streams where the use of mark-recapture methods or direct enumeration is impractical or limited by personnel or budgetary constraints. An observer may conduct one or two surveys of the creek or a portion of the creek during the spawning season. Population abundance is usually estimated by extrapolation and expressed in increments of 100 fish. This is considered the least accurate of the in-river estimation procedures and provides no statistical measure of the population estimate variance.

## **Hatchery Counts**

Hatchery counts are direct counts of the number of chinook salmon entering each of the five hatcheries in the Central Valley. These are not complete counts of the number of returning hatchery fish because variable numbers of adults stray each year and do not return to the hatchery or stream of origin. Additionally, hatchery personnel typically close the entrance to a hatchery once the required

number of adults has been obtained, thus preventing late-arriving fish from entering the hatchery. These fish may become part of the in-river spawning population.

Efforts to estimate the contribution of hatchery production to total adult escapement (Dettman and Kelley 1986, 1987; Cramer 1990) have been hampered by hatchery-produced fish mixing with naturally produced fish on the spawning grounds and the lack of a consistent marking program aimed at discriminating these stocks. Although hatcheries release some fish with identifying marks and tags, usually an adipose fin clip and a binary-coded magnetic wire tag inserted in the nasal region of the fish (AD-CWT), only a small, variable fraction of the releases have usually been tagged in this manner. Increasingly greater proportions of hatchery-produced fish are being marked; however, as indicated by percentages of 1995 coded-wire tagged fish released from Coleman National Fish Hatchery:

- 100% of winter-run chinook salmon (50,000 fish),
- 100% of late fall-run chinook salmon (850,000 fish),
- 8% of fall-run chinook salmon (1,000,000 fish), and
- 33% of steelhead trout (200,000 fish).

## **Ocean Commercial and Sport Harvest**

California ocean salmon harvest statistics are derived from data obtained by fishery sampling programs and records maintained by commercial salmon buyers and charter-boat operators. California's ocean fishery sampling programs are designed to sample at least 20% of the salmon (chinook and coho) landed in the commercial and sport fisheries.

Sampling is conducted at five major California ports and some small adjacent subports during the entire ocean commercial and sport fishing seasons. Sampling within the seasons is stratified by semimonthly periods. Sport fishery sampling is further stratified by weekend day, holiday, and weekday. The port sampling program provides an important opportunity to recover marked (AD-CWT) fish.

Total commercial landings by species are estimated for each port and time stratum by dividing the pounds of salmon sold to commercial salmon buyers by the average weight per salmon obtained from sample data. Total sport landings are estimated for each port and time stratum by extrapolating the number of sampled fish per day by the number of possible fishing days and number of ports.

## **Potential Revisions to Existing Methods**

The AFRP defines the restoration goal for anadromous fish to be equal to at least twice the average estimated natural production for the baseline period (1967-1991). Numeric goals have been established for each species, race, and stream (or geographic area). Natural production is measured in terms of the number of fish that are recruited to adulthood in a given year and defined to be that portion not produced in hatcheries, including newly recruited fish that are harvested. The AFRP's

average annual baseline production levels and restoration goals for each race and sub-basin are based on integrating data on:

- total spawning escapement, including in-river spawners and hatchery returns,
- inland sport harvest (i.e., harvest that occurs downstream of spawning areas),
- ocean commercial and sport harvest, and
- proportion of total adult production produced naturally and artificially.

The general computational sequence used to estimate baseline production levels and restoration goals is illustrated in Figure 3-1.

Current methods for estimating each parameter are discussed below with respect to their use in meeting monitoring requirements for the AFRP. Where shortcomings are identified, possible alternatives or revisions to existing methods are recommended.

### **In-River Populations**

**Mark-Recapture Methods.** Most estimates of baseline (1967-1991) chinook salmon spawning populations were generated using the Schaefer method. Detailed evaluations of the Schaefer and Jolly-Seber methods indicate that the Jolly-Seber method is less biased than the Schaefer method and that the Schaefer method consistently overestimates the actual population (Boydston 1994, Law 1994). Both estimates, however, are sensitive to capture conditions and depend on assumptions that are difficult to meet in large rivers. For example, capture rates are generally too low for unbiased estimates using either method.

A general criticism of the Jolly-Seber method is that it typically generates lower estimates than the Schaefer method, resulting in estimates that are not comparable to the numerous past Schaefer estimates. Unfortunately, Jolly-Seber estimates cannot be generated from existing spawning escapement data. Both methods can be used concurrently, however, because field applications are very similar. The primary difference between the two methods is that the Jolly-Seber method requires that the population be surveyed for two additional sample periods after the last tagging effort to develop an abundance estimate.

Where practical, the Schaefer method should continue to be used for future AFRP monitoring efforts. High-priority spawning areas identified by DFG include the Sacramento River between RBDD and Hamilton City, American River, Feather River, Yuba River, Battle Creek, Clear Creek, Cow Creek, Antelope Creek, Big Chico Creek, Butte Creek, Deer Creek, Mill Creek, Stanislaus River, Tuolumne River, and Merced River (California Department of Fish and Game 1995). Where estimates are currently based on index reaches or partial surveys, surveys should be extended to cover the entire spawning reach for all target streams and where possible, estimates by race should be determined. The comparability of the resulting estimates to past estimates should be examined before these estimates are used for monitoring purposes.

Snider et al. (1993) recommended that the Schaefer and Jolly-Seber methods be further evaluated for sensitivity to capture conditions (e.g., flow) during and between years and identified several alternative tagging procedures for dealing with various conditions likely to be encountered on a large river, such as the lower American River. Improvement in the accuracy of the estimates may eventually be achieved, but the Schaefer estimates should continue to serve as the basis for evaluating the success of the AFRP.

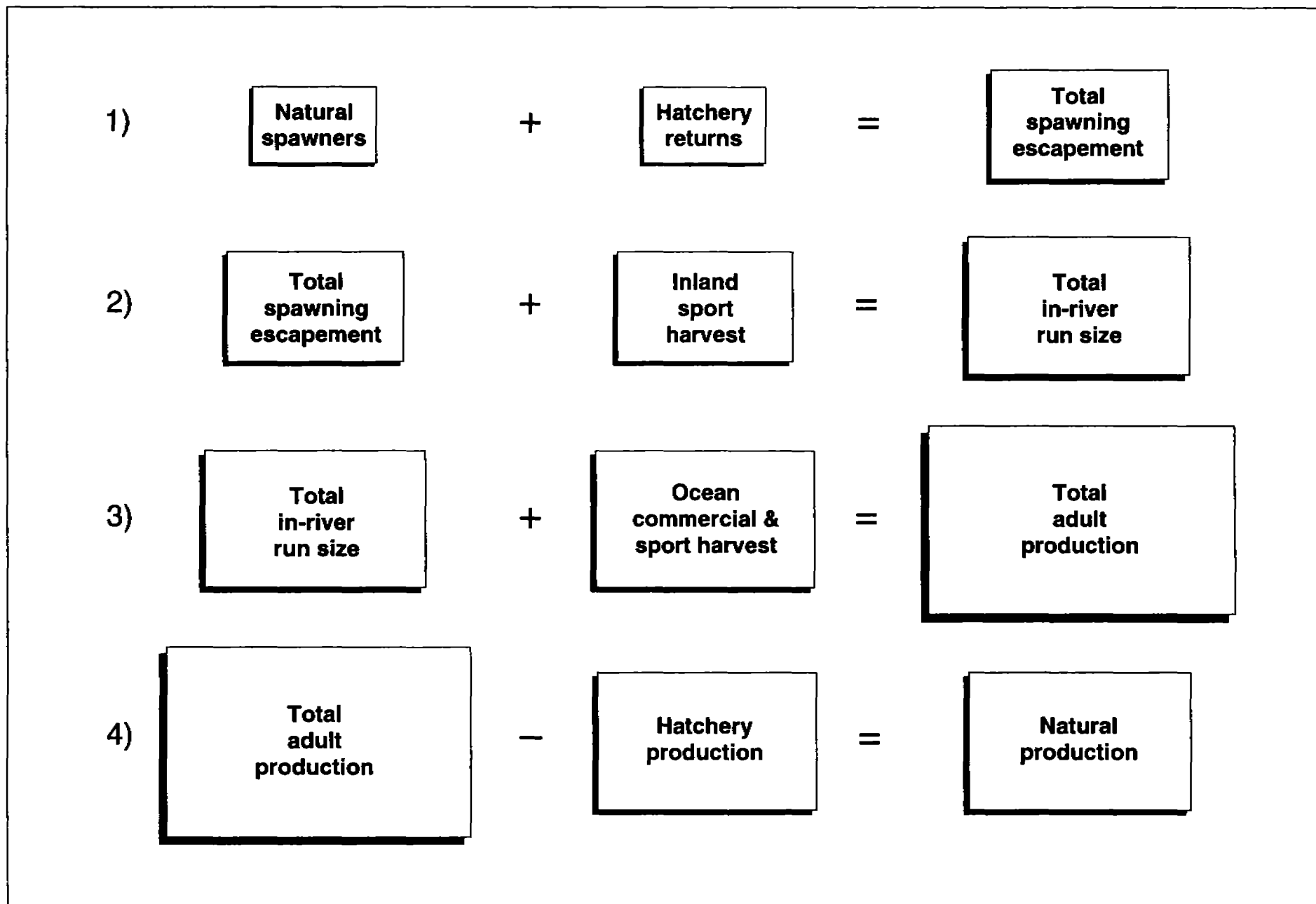
A common practice during past chinook salmon spawning escapement surveys has been to tag only adult (age 3 and older) salmon carcasses and estimate adult abundance using the Schaefer method. The total number of grilse (age-2 salmon), however, has typically been estimated from the proportion of grilse observed during the surveys. Estimating grilse in this manner is valid as long as recovery rates of adults and grilse are similar. However, tagging both adults and grilse during spawning escapement surveys in the Yuba River in 1991 and 1994 revealed that overall recovery rates of grilse were substantially lower (18% and 35%, respectively) than those for adults (Jones & Stokes Associates 1992, 1995). Boydstun (1994) found that the grilse recovery rate on Bogus Creek, a tributary of the Klamath River, was 37% lower than the adult recovery rate. These differences suggest that estimates of grilse abundance and total spawning escapement could be improved by tagging both adults and grilse and estimating their abundance independently. While this modification would improve the accuracy of spawning escapement estimates, it would also reduce the comparability of future estimates with past estimates.

Accurate age composition data are useful for monitoring and managing chinook salmon populations because such data can be used to better estimate year class strength (i.e., abundance of a group or cohort of fish originating from the same stream and spawned in the same year) and forecast expected adult populations and fishery yields. Additionally, age composition data facilitates understanding of the environmental factors influencing year-class strength and population dynamics of a salmon stock, including the effects of restoration actions implemented under the AFRP.

Tagging both adults and grilse would improve the accuracy of future estimates. The length classes used in the field to separate adults and grilse could be verified annually by determining the age and lengths of a representative sample of spawners. Scales and/or otoliths could be used to determine ages. For evaluating the AFRP goals, however, grilse abundance could continue to be estimated based on the proportion of grilse observed during field surveys.

**Direct Counts.** Direct counts of upstream migrating chinook salmon, in combination with other methods such as aerial redd counts, could be continued in streams where counting facilities currently exist. Because of changes in operation of RBDD (e.g., raising the gates for passage of winter-run chinook salmon) and proposed application of alternative water diversion technologies (e.g., screw pumps), ladder counts of fall- late fall- winter-, and spring-run chinook salmon at RBDD will become increasingly difficult or impossible to obtain in the future. Although ladder counts will be conducted whenever possible, alternative monitoring procedures will need to be developed or intensified to offset the loss of RBDD ladder counts when the RBDD gates are raised. Potential alternatives for estimating run size include electronic technologies (e.g., hydroacoustics) and mark-recapture techniques in conjunction with angler surveys. If possible, the relationship between ladder

**Figure 3-1. Generalized Computational Sequence for Estimating Baseline Production Levels and Restoration Goals for an Individual Chinook Salmon Stock**



counts and alternative abundance measures should be assessed to provide estimates that are comparable with baseline data.

**Inland Sport Harvest.** Restoration and expansion of the angler survey program initiated by DFG in 1991 would provide comprehensive monitoring of inland sport harvest of chinook salmon and other anadromous species on a long-term basis. The program could be expanded to include all of the reaches and tributaries of the Sacramento and San Joaquin basins identified as high priority because of significant sport harvest of anadromous species. These include the mainstem Sacramento, American, Feather, Yuba, and mainstem San Joaquin rivers (California Department of Fish and Game 1995a). Angler surveys could be designed to provide harvest estimates for different chinook salmon races in areas where angling regulations permit their harvest.

### **Hatchery Counts**

Counts of adult returns should be continued at the Coleman National Fish, Feather River, Nimbus, Mokelumne River, and Merced River hatcheries. The potential for counting salmon more than once by returning unspawned salmon to the river should be avoided.

### **Ocean Commercial and Sport Harvest**

Monitoring ocean commercial and sport harvests of chinook salmon is an essential element of the AFRP monitoring effort because of the substantial portion of adult production represented by this component. As proposed in the AFRP Working Paper, ocean harvest of a specific race from a specific stream or geographic area is computed by apportioning annual estimates of total ocean harvest by the proportion of total annual Central Valley run size returning to the specific stream or geographic area of origin. This assumes that all chinook salmon stocks are equally vulnerable to the ocean commercial and sport fisheries. Existing life history information indicates that the offshore distribution, maturation schedules, growth rates, and survival rates of chinook salmon vary among stocks, presumably in response to genetic and environmental factors. The distribution and level of effort of the commercial and sport fisheries varies seasonally and annually in response to regulatory and economic factors, as well as fish distribution and abundance. Thus, the assumption of equal harvest rates among stocks is tenuous at best.

Because of stock-specific goals established by the AFRP, the need exists to improve estimates of the contribution of individual salmon stocks to the ocean fishery. This is also vital to effective management of wild and hatchery stocks that may differ substantially in their capacity to withstand harvest. Coded-wire tagging has been the single most useful tool in coastwide monitoring of chinook salmon hatchery stocks and other anadromous salmonids. Unfortunately, Central Valley hatcheries typically tag only a small, variable fraction of their total annual production, making it impossible to obtain accurate harvest estimates for these stocks. This problem is compounded by the inability to distinguish Central Valley fish from those originating from outside the basin. Because only limited tagging of naturally produced or wild salmon has been conducted in past years, little is known about the distribution of these stocks or their contribution to the ocean fisheries.

A consistent, coordinated hatchery tagging program is needed to adequately assess the fishery contribution of all major Central Valley hatchery stocks and other hatchery stocks from outside the basin. Estimates of hatchery contributions to the ocean commercial and sport fisheries can then be used to estimate the harvest fraction attributable to natural production. Further estimation of the contribution of individual stocks of wild or naturally produced fish would require capturing, tagging, and releasing emigrating juveniles. The highest priority should go to stocks that are sensitive, in known decline, or substantially depressed from historical levels.

Methods for separating naturally produced and hatchery-produced fish are discussed below.

### **Natural and Hatchery Production**

Because the goal of the AFRP is to sustain natural production of anadromous species at levels not less than twice the average baseline levels, it is essential that monitoring be capable of separating the contributions of hatchery and natural production to adult populations. Past efforts to estimate the proportion of hatchery-produced fish in the annual spawning escapement of several Sacramento River tributaries (Dettman and Kelley 1986, 1987; Cramer 1990) have had limited success because of the lack of a consistent marking program aimed at discriminating natural and hatchery-produced fish. Hankin (1982) demonstrated that consistently tagging a constant fraction of all hatchery releases (in excess of CWT fish) allows estimation of the proportion of hatchery fish in a river system's run. He found that the variance of the estimate depends strongly on the fraction of releases marked in excess of CWT releases, with variance declining substantially as the fraction increases from 0.05 to 0.25 and little statistical improvement occurring with fractions above 0.50. In conjunction with implementing a fractional marking program, angler and spawning escapement surveys should be expanded to include all major angling and spawning areas in the basin to recover adequate numbers of tagged fish that do not return to the hatchery of origin. This is especially important in the Sacramento River basin because of the diversity of release groups and extensive straying of hatchery fish released outside the river of origin. DFG (1995a) assigned high priority for recovery of CWT fish to the mainstem Sacramento River from Keswick Dam to Battle Creek and the Sacramento, American, Feather, Yuba, mainstem San Joaquin, Stanislaus, Tuolumne, and Merced rivers.

Although currently not in use, alternative methods for separating naturally produced fish from hatchery-produced fish include use of scale or otolith characteristics and marking techniques such as incorporating genetic markers or inducing otolith banding patterns.

Once a program to discriminate natural and hatchery stock is initiated, the results should be used to reexamine the assumptions used to generate baseline estimates of hatchery and natural production. Baseline estimates should be adjusted if significant error is detected.

## **Monitoring Needs**

Monitoring needs for accurately assessing achievement of chinook salmon restoration goals are as follows:

- continue the use of the Schaefer method for estimating spawning escapement;
- continue counts of adult returns to all Central Valley salmon and steelhead hatcheries;
- develop or intensify alternative population estimation procedures to estimate upper Sacramento River chinook salmon runs, including electronic technology (hydroacoustics) and mark-recapture techniques in conjunction with angler surveys;
- restore and expand angler survey programs to include all reaches and streams where significant sport fisheries exist;
- continue ocean commercial and sport fishery sampling program; and
- develop a coordinated chinook salmon constant fractional marking program at appropriate Central Valley salmon hatcheries.

While more of a research need, evaluating the usefulness of the Jolly-Seber and Schaefer methods under different river conditions could provide additional insight into population estimation methods for chinook salmon.

## **STEELHEAD**

### **Population Assessment Methods**

Annual steelhead populations are not measured for most Central Valley rivers, as are fall-run chinook salmon. AFRP's steelhead doubling goal is based solely on the combination of estimated natural escapement, sport harvest, and proportion of hatchery-produced fish that spawn naturally upstream of RBDD during the 1967-1991 period. AFRP uses a three-step process for developing the annual natural production estimate.

First, steelhead population counts are made annually at RBDD, and naturally spawning fish are estimated by subtracting the number of steelhead returning to Coleman National Fish Hatchery (located on Battle Creek above RBDD).

Second, to estimate sportfishing harvest, harvest rates are determined based on angler survey data collected sporadically from 1953 through 1993 on the mainstem Sacramento River (Hallock et

al. 1961, Rowell 1980, and Wixom pers. comm. reported in Mills and Fisher [1994]). A significant relationship between RBDD counts and catch was found for these data (Mills and Fisher 1994). The annual harvest rate determined by this relationship averaged 38% of the total steelhead count at RBDD (minus Coleman National Fish Hatchery returns). The ratio of estimated angler harvest above RBDD to RBDD counts during the same period (38%) has been assumed in each year during the 1967-1991 period to estimate angler harvest. (Mills and Fisher 1994.)

Third, the proportion of hatchery-produced steelhead that spawned naturally was estimated to be 29% of the total natural escapement and sport fishing harvest. This percentage was subtracted from the total natural escapement and sport fishing harvest to arrive at the natural production estimate on an annual basis, which was averaged and doubled to determine the steelhead population goal. (U.S. Fish and Wildlife Service 1995.)

Estimates of steelhead natural production are very conservative and do not include estimates for locations where steelhead likely spawn. Sporadic estimates for some Sacramento River tributaries, such as Mill and Deer creeks, have been derived from historical and recent ladder counts. Estimates for the Yuba River are from mark-recapture experiments. Comprehensive measures of sport harvest rates have not been made on a consistent basis, but sporadic angler surveys have been made for some rivers. None of these methods or estimates have been conducted consistently over time in a manner that facilitates a scientifically defensible estimate that can be applied to total natural steelhead production in the Central Valley.

### **Potential Revisions to Existing Methods**

Steelhead population estimates for the baseline period and restoration goals are based on four population parameters:

- adult counts at RBDD;
- adult counts at Coleman National Fish Hatchery;
- the percentage of estimated angler harvest to RBDD counts (38%); and
- of the total natural escapement and the sportfishing harvest, the percentage of hatchery-produced steelhead that spawned naturally.

These four parameters, and several additional parameters only indirectly related to evaluating the restoration goals, are discussed below.

## Adult Counts at RBDD

With the completion of RBDD in 1967 and its associated fish-counting facilities, steelhead could be systematically counted. The annual adult steelhead count at RBDD provides the basis for developing the steelhead restoration goal. The AFRP, however, has a restoration action plan to raise the RBDD gates for a minimum period from September 15 to May 30 each year. If this action is implemented on a long-term basis, steelhead counts at RBDD will be very limited using current techniques, and monitoring the effectiveness of the steelhead restoration goal would be substantially reduced. Additional data collection would be required to offset the loss of RBDD ladder counts.

If a thorough angler survey program was conducted each year on the Sacramento River, the existing steelhead abundance and harvest relationship could be used to estimate steelhead abundance. Such a method would necessarily assume that the existing abundance and harvest relationship is valid. This relationship is somewhat questionable, however, because of several problems with the existing relationship between annual steelhead populations and harvest (McEwan pers. comm.):

- Hallock et al. (1961) estimates include fish  $\geq 14$  inches long, which includes resident rainbow trout;
- Wixom et al. (1995) estimates include yearling steelhead and hatchery plants because clerks did not record the size of creeled fish; and
- the 38% average harvest rate appears too high when the range elsewhere is 7-29%.

An intensive angler survey program would need to be similar in design to those conducted previously (Hallock et al. 1961, Rowell 1980, and Wixom et al. 1995), but would need to be modified and augmented with additional studies to accurately determine adult counts at RBDD and adjust for past sampling discrepancies.

Other types of adult monitoring, such as mark-recapture methods, direct counts, spawning index reaches, or hydroacoustic monitoring at RBDD, would be difficult to implement for a variety of reasons primarily related to the small number of naturally produced steelhead, poor access into many of the key steelhead spawning areas, and poor (winter) conditions for sampling or counting adult steelhead. Index streams could provide valuable information in the future, but at present there are few streams with steelhead population estimates and those estimates are not consistent over time.

## Adult Counts at Coleman National Fish Hatchery

Adult steelhead counts at Coleman National Fish Hatchery are relatively easy to obtain and are generally consistent with the annual estimates of adult steelhead abundance in the upper Sacramento River. These counts are not a surrogate for counts at RBDD because these hatchery counts do not provide a sufficient basis for determining the number of naturally produced fish and do not provide specific data on naturally produced populations, which are estimated to be 10-30% of the

steelhead run in the upper Sacramento River (Fisher pers. comm. reported in McEwan and Jackson 1994).

### **Percentage of Estimated Angler Harvest to RBDD Counts**

Ladder counts of steelhead trout have been used to estimate angler harvest, based on the historical relationship between angler harvest and RBDD steelhead counts. Without the RBDD counts in the future, however, expansion of the angler survey program as described above, with additional verification or modification of several assumptions used in the past, is necessary to ensure an accurate estimate of harvest, which could be used to estimate steelhead populations passing RBDD. In addition, any changes in sportfishing regulations could affect the percentage of harvest and, consequently, this estimation method.

### **Percentage of Hatchery-Produced Steelhead That Spawned Naturally**

Of the total natural escapement and sportfishing harvest, the percentage of hatchery-produced steelhead that spawned naturally is solely based on professional judgment; an assumed percentage of 29% was used by the AFRP to develop its steelhead restoration goal. This percentage is based on the assumption that 50% of hatchery fish do not return to the hatchery, but spawn in-river. An extensive mark-recapture program would be needed to determine the accuracy of the estimate.

The ratio of naturally produced and hatchery-produced steelhead should be a factor in any study design to monitor natural steelhead populations over time. Comprehensive and consistent mark-recapture programs have not been conducted for steelhead in the past, but DFG's draft steelhead management plan recommends marking of all hatchery steelhead. The natural production of steelhead could be more accurately estimated if such programs or baseline research were implemented. This is especially true with respect to potential AFRP actions that, while beneficial to natural steelhead stocks, could change the relationship between natural and hatchery-produced steelhead by:

- avoiding potential competitive displacement of wild, naturally produced juveniles with hatchery-released juveniles by stabilizing hatchery production levels and implementing release strategies designed to minimize detrimental interactions;
- implementing specific hatchery spawning protocols and genetic evaluation programs to maintain genetic diversity in hatchery and wild stocks; or
- changing hatchery production or release patterns in any way to benefit naturally producing stocks.

## Other Parameters

Steelhead restoration goals, as expressed in the Service's Working Paper (U.S. Fish and Wildlife Service 1995) are not watershed-specific, as are chinook salmon goals, because of lack of information on watershed-specific, naturally produced steelhead populations. Although such data are not directly relevant to monitoring the effectiveness of 3406(b) actions in meeting the Service's steelhead restoration goal, any additional counts that currently are made at weirs, ladders, dams, or diversions would be valuable because of the relative lack of steelhead population data, particularly watershed-specific data. An estimated 25% of all naturally produced steelhead migrating into the upper Sacramento River system spawn in Deer, Mill, and Antelope creeks (U.S. Fish and Wildlife Service 1995); therefore, these may be three stream systems where emphasis could be placed to provide additional long-term population counts.

## Monitoring Needs

Monitoring needs for accurately assessing achievement of the steelhead restoration goal are as follows:

- continue adult counts on Mill and Deer creeks,
- continue adult counts at Coleman National Fish Hatchery,
- develop a comprehensive angler survey program on the Sacramento River to accurately and precisely estimate angler harvest to provide an estimate of adult steelhead passing RBDD,
- continue to calculate the number of hatchery-produced steelhead that spawned naturally as 29% of the total natural escapement and sportfishing harvest, and
- develop a coordinated steelhead constant fractional marking program at appropriate Central Valley hatcheries that, in conjunction with a comprehensive angler survey, would permit estimates of hatchery contribution to adult populations.

Although not absolutely needed to monitor populations consistent with baseline (1967-1991) methods, a steelhead marking program should be implemented at all steelhead-producing Central Valley hatcheries. This would substantially reduce the number of assumptions currently necessary to determine abundance estimates for naturally produced steelhead. Other sampling programs or even new data analyses could be specifically designed to evaluate the numeric assumptions that were used by AFRP to estimate naturally produced steelhead abundance. Such sampling programs or new analyses would be used to develop a better estimator of steelhead trout abundance passing RBDD. DFG also recommends monitoring Yuba River steelhead populations (Mills pers. comm.).

## STRIPED BASS

### Population Assessment Methods

Baseline abundance of adult striped bass (fish  $\geq 15$  inches fork length before 1982 and fish  $\geq 16.5$  inches fork length since 1982) was estimated by mark-recapture studies conducted since 1969 in the Bay, Delta, and lower rivers. Gill nets and fyke traps are used to capture bass during their spring migration to the Delta and lower Sacramento River. The percentage of marked fish recovered during angler surveys and subsequent tagging provides the basis for a standard modified Petersen population estimate. From 3,100 to 18,400 adult striped bass were tagged each year during the baseline period. Abundance estimation procedures are complicated by sex- and age-sampling biases; therefore, all tagging and recapture samples are stratified by sex and age. (Stevens 1977, U.S. Fish and Wildlife Service 1995.)

The tagging effort is accomplished using gill nets 5 days per week in the western Delta during April and May, and fyke traps continuously in the Sacramento River near Knights Landing from late March or early April through mid- to late June. Disk-dangler tags are applied to the fish before their release. Sex is determined by examining fish for milt. Age is determined from scale samples (Stevens 1977, U.S. Fish and Wildlife Service 1995). For both tagged and angler surveyed fish, a computer program uses an age-length key developed from the aged fish to apportion nonaged fish into the appropriate age classes (Stevens 1977, Mills and Fisher 1994). Tagging efforts could be conducted biennially, along with the annual angler surveys, and still provide monitoring to develop adequate striped bass population estimates (Stevens pers. comm.).

Angler surveys are carried out year-round. Angler survey clerks sample angler catch at four to six ports at a time. They observed from 1,500 to 38,700 adult bass with 16 to 891 tags per year during the baseline period. The tagged to untagged ratio in the angler survey recovery ranged from 1:37 to 1:108 during the baseline period. (U.S. Fish and Wildlife Service 1995.)

Juvenile striped bass indices (summer midwater trawl, fall tow net survey) have been used to represent production of young striped bass. Because the restoration goal target life stage is adults, and because the mark-recapture program provides adequate estimates of adult abundance, estimates of young bass production are not necessary for meeting CAMP's primary goal of assessing long-term population trends. Such juvenile production data, however, is important in evaluating the effectiveness of action categories on striped bass (CAMP Goal #2).

## Potential Revisions to Existing Methods

The striped bass mark-recapture program and adult population estimates are adequate for evaluating the AFRP restoration goal for striped bass. Biennial estimates also provide adequate accuracy and precision when annual estimates are not possible because of fiscal constraints (Kohlhorst pers. comm.). The program, as conducted, depends on 1) biennial tagging efforts to ensure adequate numbers of tags are distributed into the population, and 2) annual angler surveys to determine the proportion of tags in the adult population. Both of these efforts should be continued at least at present levels to meet CAMP needs and provide consistent striped bass population estimates.

## Monitoring Needs

Monitoring needs for accurately assessing achievement of the striped bass restoration goal are as follows:

- continue the existing mark-recapture program for adult striped bass and
- continue current calculation of adult population estimates. .

## AMERICAN SHAD

### Population Assessment Methods

Juvenile abundance in DFG's fall midwater trawl (MWT) survey is used to develop a juvenile shad MWT index because there are no data to estimate the adult component of the American shad population for any baseline years except 1976 and 1977. This index is used as a surrogate for an adult shad doubling goal because of the limited sample size of adult estimates during the baseline period. The MWT survey is conducted at about 90 sampling sites from the Delta downstream through San Pablo Bay from September to December. To reflect the fact that the juvenile index is related to abundance of spawning adults 3-5 years later, it would have been ideal to consider the index for 1962-1988. Because the MWT survey was not begun until 1967, however, it was necessary to estimate the baseline period average and to establish the restoration goal on the basis of data collected from 1967 through 1988. Additional deficiencies in MWT data occur because sampling does not include the entire period that juvenile shad are present in the system and because a portion of the system that is known to be used by juvenile shad is not sampled at all. (U.S. Fish and Wildlife Service 1995.)

Several other methods to assess American shad populations have been conducted sporadically and were not used in developing the American shad restoration goal. Since 1974, adult shad have been caught annually in striped bass fyke traps set periodically in the Sacramento River, but the data are not continuous in either time or space, the locations of the traps have changed several times above

and below major shad spawning rivers, and the goal of this sampling program was never intended to develop population estimates for shad. CVP and State Water Project (SWP) salvage abundance indices provide data primarily on young-of-the-year shad but are biased by Delta flow patterns, which vary substantially on an annual basis. The Service's beach seine survey data contained very low sample sizes of shad, and variations in any beach seine index were extreme. Spring and summer MWT data include shad, but sampling occurs only at one site too early in the year to include the bulk of the American shad production. Random angler surveys for shad have been done to estimate the number caught by anglers in the Delta and rivers but, again, these data have not been collected in a consistent manner. The only major shad research investigation conducted was in the mid-1970s (Painter et al. 1980).

### **Potential Revisions to Existing Methods**

Given the extremely limited baseline data on adult shad population levels, the juvenile shad MWT index provides a reasonable means for measuring the goal of doubling American shad production in the Central Valley. Consequently, no change is recommended to the current fall MWT program. The program, continued in its current form on a long-term basis, will provide the necessary data for calculating the juvenile shad population index. The current program does not address adult shad and presumes a linear relationship between the juvenile shad MWT index and the number of shad returning to spawn in subsequent years.

While not directly related to evaluation of the shad doubling goal, additional monitoring of adult shad populations is desirable to evaluate the relationship between the juvenile shad MWT index and returning adult shad populations. At present, few data are available to test the assumption that this relationship is valid. The only intensive shad investigation ever conducted in California that would have addressed this relationship was terminated prior to its completion (Painter et al. 1980). Many of the recommendations from this study would be useful in designing and implementing a comprehensive tagging study to determine adult population levels; field methods have already been tested to guide future efforts (Painter 1976).

A large-scale mark-recapture program for adult shad may not be possible at this time because of fiscal constraints and funding priorities. Expanded angler survey information, however, could provide an index of population abundance within any or all of the major spawning rivers: the Feather, Yuba, American, and upper Sacramento rivers. Study designs consisting of direct counts of adult shad in specific spawning reaches could also be employed. These types of adult population indices, if developed in a standardized and consistent fashion and adjusted for variations between angling success and spring flow conditions, would provide additional information that could be used effectively to verify the link between the juvenile shad MWT index and actual adult shad population levels.

## **Monitoring Needs**

Monitoring needs for accurately assessing achievement of the American shad restoration goal are as follows:

- continue the fall MWT surveys consistent with the 1967-1991 period and
- calculate the juvenile shad MWT abundance index annually.

While not considered a monitoring "need", angler surveys in the Yuba, Feather and American rivers could provide valuable indices of adult population estimates and provide opportunities to establish adult shad population monitoring goals in the future.

## **WHITE STURGEON AND GREEN STURGEON**

### **Population Assessment Methods**

Tagging studies have provided mark-recapture estimates of abundance of legal-sized white sturgeon ( $\geq 40$  inches total length). For the 1967-1991 baseline period, mark-recapture estimates are available for only 8 years (1967, 1968, 1974, 1979, 1984, 1985, 1987, and 1990) because of the intermittent nature of the past tagging program. In fall, white sturgeon and green sturgeon are captured in trammel nets in San Pablo Bay and occasionally in Suisun Bay. The sturgeon are tagged with \$20 disk-dangler-reward tags below the anterior end of the dorsal fin. Information recorded includes sturgeon length and release location, tagger, date, and condition of the fish. Tagged sturgeon are released near the site where they are captured (Kohlhorst et al. 1991). Currently, DFG proposes to tag legal-sized sturgeon in alternate years (when striped bass are not tagged) (Kohlhorst pers. comm.).

All tag recaptures in the trammel nets are recorded and used in conjunction with the number tagged to estimate white sturgeon abundance in one of two ways. In years when a recapture sample is available from tagging, white sturgeon abundance is estimated using the Adjusted Petersen Method. When adequate recapture samples from later years are not available, the multiple census method of Schumacher and Eschmeyer is used, based on recaptures during the same season tagged. (Kohlhorst et al. 1991.)

Annual white sturgeon harvest and natural production estimates for the baseline period were available for the 8 years defined above and were used to establish the restoration goals. Annual population estimates in years for which data are unavailable have been extrapolated from these 8 years in some cases (Mills and Fisher 1994) but were not used by the AFRP in establishing the restoration goals. Catch is estimated by multiplying the population estimate by the harvest rate. Production is estimated by multiplying the population estimate by the estimated fraction of the population that is 15 years old, which is determined through length-age analysis. Age 15 is approximately the mean age

of recruitment of females to the white sturgeon spawning population. Escapement is not addressed because of the multi-aged spawning population structure of sturgeon. (U.S. Fish and Wildlife Service 1995.)

The current tagging program is the minimum sampling that will adequately monitor trends in legal-sized white sturgeon abundance, catch, and natural production. At recent low population levels, however, the program often does not provide sample sizes large enough to calculate reliable estimates of abundance (multiple census and Petersen mark-recapture), catch, and natural production. Monitoring programs to determine white sturgeon year-class strength are not relevant to CAMP's primary goal of evaluating long-term population trends.

Few green sturgeon were tagged each year during the baseline period, and none were recaptured during tagging; hence, no independent estimate of their abundance was possible. Instead, green sturgeon abundance (not natural production as with white sturgeon) is estimated by dividing white sturgeon abundance estimates by the ratio of white sturgeon to green sturgeon observed during tagging. This ratio averaged 78.9:1 and, given the mean white sturgeon abundance during the baseline period (77,525), green sturgeon abundance was estimated at 983 fish. The restoration goal for green sturgeon was established at 2,000 fish. (U.S. Fish and Wildlife Service 1995.)

### **Potential Revisions to Existing Methods**

The current program for estimating the number of legal-sized white sturgeon populations is essentially the same as was used during the 1967-1991 baseline period. To evaluate whether white sturgeon restoration goals are being met over time, the program must be continued into the future at least at the same level of effort and using the same design used during the baseline period.

The program, however, is not extensive and has limitations. Tagging efforts on sturgeon are limited and confined to a short season and restricted to the portion of the population that resides in San Pablo Bay. Recovery is also limited to this same tagging program, and not all age groups or subpopulations are sampled by this survey program. In recent years, sample sizes have often been too small to provide reliable abundance estimates. Explicit assumptions in the sturgeon mark-recapture program that may be violated are:

- random distribution of tagged sturgeon in the nontagged population,
- equal capture probability of tagged and nontagged fish, and
- a closed population (i.e., the proportion of the entire population represented by the estimate is unknown and may vary between estimates) (Mills and Fisher 1994).

A more expansive marking and recovery program implemented annually for white sturgeon would provide greater insight into the extent of the potential biases and provide more reliable population estimates. Marking could be expanded in time and location. Recovery could also be expanded and include an angler survey. Such an expanded program would help determine the need for additional surveys, depending on initial survey results.

A more expansive program could also be tailored to provide an independent population estimate for green sturgeon. Currently, assumptions used to calculate green sturgeon abundance are that green sturgeon and white sturgeon are equally vulnerable to trammel nets, green sturgeon and white sturgeon are randomly dispersed, and equal proportions of the populations of these species reside within the sampling area (U.S. Fish and Wildlife Service 1995). These assumptions are likely violated in many instances, and an expanded program could provide greatly improved abundance estimates for green sturgeon if desired.

### **Monitoring Needs**

Monitoring needs for accurately assessing the achievement of white sturgeon and green sturgeon restoration goals are as follows:

- continue the existing mark-recapture program for adult white sturgeon;
- estimate abundance, catch, and natural production for age 15 white sturgeon as currently calculated; and
- estimate the adult population of green sturgeon as currently calculated.

In addition, existing programs could be expanded to provide more accurate adult estimates of white sturgeon. Such program expansion is not currently considered critical to CAMP's need but would provide a better and more accurate scientific basis for estimating white sturgeon and green sturgeon population levels.

## **Monitoring Methods and Needs for Assessing Effectiveness of Action Categories in Doubling Populations (CAMP Goal #2)**

## **Chapter 4. Monitoring Methods and Needs for Assessing Effectiveness of Action Categories in Doubling Populations (CAMP Goal #2)**

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### **INTRODUCTION**

CAMP's primary goal is to evaluate the overall (cumulative) effectiveness of actions implemented pursuant to CVPIA Section 3406(b). CAMP's primary goal requires only that anadromous species and races be monitored, which can be accomplished by monitoring species population estimates on a consistent basis by means consistent with the baseline period (1967-1991) methods. The secondary goal of CAMP, which is to determine the relative effectiveness of each of four categories of actions (water management modifications, structural modifications, habitat restoration, and fish screens) in meeting Section 3406(b) doubling goals, is addressed in this chapter. This goal is distinct from CAMP's primary goal because determining the effectiveness of four action categories begins to address the question of *why* the anadromous populations have been doubled (or not doubled) on a long-term basis. That is, which action category most effectively restores naturally produced populations of anadromous fish? Meeting this CAMP goal is a much more complex task, as will be shown throughout this chapter.

Evaluating the effectiveness of each category of actions in restoring anadromous fish populations is important for several reasons. Controversy currently surrounds the allocation of an increasing portion of California's water resources from current uses (such as agricultural, urban, municipal, industrial, and power generation uses) to anadromous fisheries needs. The use of flows to restore fish production is intensely debated among various water users and fisheries scientists because the relationship between flows and the status of fish populations is not always clearly understood or documented. Additionally, the costs to agricultural and urban water users associated with increased instream flows are considered to be significantly greater than the costs associated with structural modifications and fish screens. The role of water management modifications (modified operations or releases specifically for fisheries restoration needs) in achieving doubling goals needs to be understood and documented to the degree possible.

Of critical concern in the value of any restoration action is whether the action addresses the factors that are limiting fish populations. For example, screened diversions that prevent entrainment of juvenile fish may appear cost-effective and biologically beneficial, but the value of protecting those juveniles is limited if returning adults are unable to use or gain access to spawning gravels because of insufficient and/or unreliable flows in subsequent years. Evaluating the general contribution made by each of the categories of actions, therefore, is important to ensure that resources are allocated appropriately to restore fish populations.

## **Action Categories**

Actions included in Section 3406(b) have been initially grouped into the following four categories to facilitate their evaluation in CAMP:

- **water management modifications**
  - (b)(1)(B) modify CVP operations
  - (b)(2) manage 800,000 af of CVP yield for fish, wildlife, and habitat restoration
  - (b)(3) acquire supplemental water for fish and wildlife
  - (b)(7) meet CVP flow standards that apply to CVP
  - (b)(8) use pulse flows to increase migratory fish survival
  - (b)(9) eliminate fish losses due to CVP flow fluctuations
  - (b)(12) provide increased flows in Clear Creek
  - (b)(19) reevaluate carryover storage criteria
- **structural modifications**
  - (b)(4) mitigate for Tracy Pumping Plant operations
  - (b)(5) mitigate for Contra Costa Canal Pumping Plant operations
  - (b)(6) install temperature control device at Shasta Dam
  - (b)(10) minimize fish passage problems at RBDD
  - (b)(11) implement Coleman National Fish Hatchery Plan and modify Keswick Dam Fish Trap
  - (b)(14) install new control structures at Delta Cross Channel and Georgiana Slough
  - (b)(15) install a barrier at head of Old River
  - (b)(17) resolve fish passage and stranding problems at Anderson-Cottonwood Irrigation District Diversion Dam
  - (b)(20) mitigate for the Glenn-Colusa Irrigation District's Hamilton City Pumping Plant
- **habitat restoration**
  - (b)(12) improve fish passage and restore habitat in Clear Creek
  - (b)(13) replenish spawning gravel and restore riparian habitat below Shasta, Folsom, and New Melones reservoirs
- **fish screens**
  - (b)(21) develop measures to avoid fish losses resulting from unscreened or inadequately screened diversions

Several Section 3406(b) subsections include both water management and structural modifications. Consequently, assessing the relative effectiveness of the four action categories will need to consider specific actions actually implemented in watersheds on a case-by-case basis.

Several sections of 3406(b) are not included in the categories of actions. Section 3406(b)(16), which directs development of CAMP, will not provide direct restoration benefits to anadromous fishes and therefore was not included in an action category. Section 3406(b)(18), which calls for restoring the striped bass fishery in the Bay-Delta if requested by the State of California, does not have specifications that currently can be addressed and is not included in any of the four categories. Section 3406(b)(22), which provides incentives for farmers to maintain flooded fields to create waterfowl habitat, represents a fifth action category that addresses specific needs for waterfowl, rather than needs for anadromous fish populations. Section 3406(b)(22) has been considered separately in Appendix A. Section 3406(b)(23), which represents Trinity River restoration, is addressed in a separate program.

Section 3406(b)(1), which establishes the AFRP and mandates all reasonable efforts be made to at least double the average 1967-1991 natural production of anadromous fishes on a long-term basis, is broad-ranging and requires a variety of actions throughout Central Valley streams to address the goals. The AFRP Working Paper identified a multitude of possible actions, most of which fall within one of the four action categories listed above. The Service is currently prioritizing these actions, not all of which are expected to be included in the AFRP Restoration Plan. This chapter generally separates the AFRP (b)(1) actions from all of the other Section 3406(b) provisions because the AFRP actions are currently undergoing prioritization, and it is unclear which, and when, specific AFRP actions will be implemented in the future.

### **Limiting Factors**

The four categories of actions represent, to the degree possible, actions included in Section 3406(b) that are designed to mitigate several of the primary factors currently thought to have contributed to the decline of anadromous fish populations in the Central Valley. These factors, which correspond to the categories of actions, are:

- reduced and altered timing of flows in Central Valley streams and rivers associated with reservoir storage; power generation; and agricultural, municipal, and industrial water conveyance, diversions, and Delta exports (water management);
- structural characteristics of dams and water conveyance facilities that adversely affect fish populations by impeding migration or altering water temperatures (structures);
- degraded and reduced instream habitat caused by lack of gravel recruitment and lack of peak flushing flows (both caused by dam operation), instream gravel mining, sedimentation, and loss of riparian habitat (habitat restoration); and
- fish entrainment and losses at unscreened or inadequately screened diversions (screens).

Generally, none of the four factors that have contributed to the decline of anadromous fish populations operates independently of the others. More often than not, there are synergistic

relationships between the factors that affect populations to an even greater degree than the sum total of each factor operating independently. Reduced or modified flows directly affect anadromous fish populations by preventing or delaying adult migration to optimum spawning habitats, reducing success of juvenile outmigration, and modifying microhabitat conditions (depths, velocities, and cover availability) important for fish feeding, resting, predation avoidance, and energetics. These factors ultimately affect production through changes in survival, growth, and reproduction. Indirectly, reduced or modified flow patterns can reduce gravel and woody debris recruitment, deposit fine sediment in existing spawning habitat, create deleterious water temperatures, alter invertebrate populations, and change the fundamental geomorphological structure and function of river ecosystems. Physical barriers to fish passage also affect habitat accessibility, reduce gravel and woody debris recruitment, and disrupt the timing and amount of natural flows. Habitat restoration efforts may restore the spawning gravels and riparian vegetation that can prevent high water temperatures and provide important physical habitat components, but the success of these actions can sometimes be greatly enhanced when coupled with appropriate and sufficient flows regimes.

## METHODS

A systematic approach was used to address the factors potentially constraining the assessment of the relative effectiveness of the categories of actions. All actions, including those recommended as part of Section 3406(b)(1) for mainstem rivers and tributaries in the AFRP Working Paper, were assigned to one of the four categories of actions. For ease of evaluation, available information considered important to distinguish effectiveness of the categories of action was collected and mapped as several GIS layers. This information included:

- geographic (site-specific) location of categories of actions when actions are specifically identified in Section 3406(b) provisions (for example, 3406[b][6] to install a temperature control device at Shasta Dam);
- potential geographic (non-site-specific) location of categories of actions when actions are only generally identified in Section 3406(b) provisions (for example, 3406[b][3] to acquire supplemental water for fish and wildlife);
- potential geographic (site-specific) location of categories of actions recommended for each tributary by the AFRP Working Paper produced under 3406(b)(1);
- population goals of anadromous fish populations of interest including fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; striped bass; American shad; white sturgeon; and green sturgeon in CVP and non-CVP watersheds (including the Delta) that are known or potential targets of actions under CVPIA; and
- geographic (site-specific) location of existing juvenile and adult chinook salmon monitoring programs.

The geographic distribution of categories of actions in watersheds throughout the system was reviewed with the intent of identifying watersheds, if any, in which a single category of actions is proposed for implementation. These watersheds would most effectively allow at least partial isolation and monitoring of the effectiveness of each category of actions.

The distribution and abundance of anadromous fish populations of interest were reviewed to determine those that are most useful in evaluating the effectiveness among categories of actions. Races or species that would be expected to have the highest value include:

- those with broad distribution in watersheds throughout the system so that different categories of actions could theoretically act on different (partially isolated) populations of fish and facilitate evaluation of effectiveness for each action category;
- those occurring in sufficient numbers that monitoring could detect significant changes or trends in abundance;
- those with populations isolated in a mainstem river or in tributaries that are sufficiently isolated to minimize exposure to environmental variables not associated with the categories of actions (e.g., hatchery influence) and to allow differentiation from other spawning populations;
- those with the most accurate baseline (1967-1991) abundance estimates;
- those with juvenile production estimates;
- those with a relatively high level of appropriate existing or future monitoring to minimize, to the degree possible, the need to develop additional monitoring programs solely for CAMP; and
- those that are not supplemented with artificial (hatchery) stocking programs or that are only minimally supplemented.

## RESULTS

### Target Species and Races

Table 4-1 presents results of applying the desired characteristics for CAMP's monitoring of the effectiveness of the four action categories to species and races. Fall-run chinook salmon was determined to be the most appropriate species and race for assessing the effectiveness of categories of actions. Fall-run chinook salmon are sufficiently distributed throughout the system to provide the flexibility needed to identify locations to isolate categories of actions and occur in sufficient numbers to permit changes in abundance to be detected reliably over time. Fall-run chinook salmon also are

the subject of the most extensive existing monitoring of juvenile production and are generally considered to be the most economically important anadromous fish species in California.

Winter- and spring-run chinook salmon, while not abundant, also have several desirable CAMP monitoring characteristics and are the focus of a high level of existing and future monitoring. Additionally, programs established for fall-run chinook salmon can be modified to provide valuable information on winter- and spring-run chinook salmon. Numerous restoration actions are targeted at spring-run chinook salmon, and good opportunities are available to evaluate spring-run chinook salmon responses to these actions. Unlike the other three chinook races, late fall-run chinook salmon have few of the monitoring characteristics desired by CAMP and there is no doubling goal to measure whether the goal is achieved.

Steelhead trout have several of the monitoring problems associated with late fall-run chinook salmon. The extensive and expensive monitoring required to determine the effects of the four action categories would go far beyond what is envisioned for CAMP at this time. The relative dearth of accurate 1967-1991 population estimates (except for the RBDD counts) and juvenile production estimates makes it difficult to establish any baseline by which the action categories can be compared. Use of steelhead juvenile production estimates is confounded by a general lack of steelhead monitoring throughout the system. For these reasons, steelhead trout are not currently a desirable indicator species for assessing the effectiveness of the four action categories. If additional monitoring data on steelhead populations becomes available, however, CAMP is sufficiently flexible to add steelhead as an indicator species for evaluating action categories.

Striped bass have six characteristics desired by CAMP. The species is highly dependent on the estuary for successful production and is the only species that can be used as a "control" for actions affecting the Delta. All other species will be significantly affected by all four categories of actions in the mainstem Sacramento River and its tributaries. The predominant change in the Delta may be from water modifications, at least until structural modifications are implemented. The extensive database of both juvenile and adult striped bass is desirable for CAMP, and the species' key reliance on Delta conditions makes it useful as a target species for the narrow focus of evaluating the four categories of actions (but primarily water management) in the Delta.

American shad have spawning populations primarily in Sacramento River tributaries, the mainstem Sacramento River, and the Delta. These populations, however, are not thought to be genetically distinct populations. Additionally, much less is known of shad ecology and population dynamics in California compared with the other anadromous species. The population goal for shad is measured as a juvenile index in the Delta, despite a large proportion of the spawning population and production occurring far upstream in several major Sacramento River tributaries. These three factors make it very difficult to use American shad as a target species for determining the effectiveness of the four categories of actions.

White sturgeon and green sturgeon have very few of the desirable characteristics for assessing effectiveness of action categories. There is a great need to develop a juvenile abundance index for white sturgeon because the long-lived adults are subject to many years of highly variable factors, and it is difficult to isolate and identify in any scientific manner which factors affect white sturgeon

Table 4-1. Desirable CAMP Monitoring Characteristics by Species and Race  
for Evaluating Effectiveness of Action Categories

Species/Race	Desired Characteristic						
	Distribution in Several Watersheds	Abundant	Isolated in Mainstem Rivers or Tributaries	Accurate 1967-1991 Estimates Available	Juvenile Production Estimates Available	High Level of Existing/Future Monitoring	Minimal or No Artificial Production
Chinook salmon	X	X	X	X	X	X	
Fall-run	X	X	X	X	X	X	
Late fall-run			X	X			
Winter-run			X	X		X	X
Spring-run	X		X	X		X	
Steelhead trout	X		X				
Striped bass	X	X		X	X	X	X
American shad	X	X			X		X
White sturgeon				X			X
Green sturgeon							X

<sup>a</sup> The desirability of these monitoring characteristics is explained at the end of the "Methods" section in this chapter.

<sup>b</sup> American shad are not considered to be isolated in tributaries because their use of tributaries is largely flow-dependent, and discrete populations within watersheds are not known to exist. American shad 1967-1991 estimates are not considered accurate because they represent an index and not an absolute population estimate.

<sup>c</sup> Winter-run chinook salmon hatchery production at Coleman National Fish Hatchery is currently on hold.

<sup>d</sup> Accurate estimates of late fall-run chinook salmon are no longer possible since 1993 because the RBDD gates are raised during their upstream migration.

using tributaries rather than mainstem rivers is the relative ability to isolate categories of actions, thus minimizing the additive or multiplicative effects of numerous CVPIA and non-CVPIA environmental variables. Exceptions include winter-run chinook salmon, which spawn and rear primarily in the mainstem Sacramento River, and striped bass, for which extensive juvenile population data are available from estuarine sampling. Obtaining accurate juvenile production estimates for salmonids will be difficult, but the AFRP will be proposing such studies in the near future.

While both adults and juveniles should be the target life stages for directly evaluating the effectiveness of the four action categories, a link should be established between any juvenile production or survival indices and adult populations. Only in this way can the effectiveness of the action categories be related back to the doubling goals, which are measured in terms of the numbers of adult fish for these target species/races. This task is easier said than done, however, and represents one of the major obstacles in fully understanding the link between fish population dynamics and presumed limiting factors. Nonetheless, such links will need to be established, over time, to provide the most meaningful results for CAMP.

### **Monitoring Locations**

Review of the geographic distribution of the categories of actions indicates that, based on CVPIA actions and AFRP preliminary recommendations, there are no watersheds in which a single category of actions is intended for implementation (Tables 4-2 and 4-3). In all watersheds, more than one action category is recommended, which suggests that the effects of action categories cannot be isolated in any watershed based on current recommendations. Although unlikely, action categories might be implemented in a predictable sequence in watersheds, and opportunities may arise where the effects of a single action category can be monitored in isolation until other action categories are implemented. Additional information on monitoring locations is presented in Chapter 5, "Conceptual Monitoring Program" on a species-specific basis.

Table 4-2. CVPIA Section 3406(b) Provisions and Action Categories by Watershed  
(Shown in Table 4-3)

Geographic Area	Section 3406(b) Provision Numbers	Action Categories			
		Water	Structural	Habitat	Screening
<b>Upper Sacramento River<sup>a</sup></b>	1B,2,3,6,7,8,9,10,11,13,17,19,21	X	X	X	X
<b>Upper Sacramento River Tributaries:</b>					
Clear Creek	1B,2,3,7,8,9,12,21	X	X	X	X
Cow Creek	3,21	X			X
Bear Creek	3,21	X			X
Cottonwood Creek	3,21	X			X
Battle Creek	3,11,21	X			X
Paynes Creek	3,21	X			X
Antelope Creek	3,21	X			X
Blder Creek	3,21	X			X
Mill Creek	3,21	X			X
Thomas Creek	3,21	X			X
Deer Creek	3,21	X			X
Stony Creek	1B,2,3,7,8,9,19,21	X			X
Big Chico Creek	3,21	X			X
Butte Creek	3,21	X			X
Miscellaneous small tributaries	3,21	X			X
<b>Lower Sacramento River<sup>a</sup></b>	1B,2,7,8,9,20,21	X			X
<b>Lower Sacramento River and Delta Tributaries:</b>					
Feather River	3,21	X			X
Yuba River	3,21	X			X
Bear River	3,21	X			X
American River	1B,2,3,7,8,9,13,19,21	X		X	X
Mokelumne River	3,21	X			X
Cosumnes River	3,21	X			X
Calaveras River	3,21	X			X
<b>San Joaquin River Basin</b>					
Merced River	3,21	X			X
Tuolumne River	3,21	X			X
Stanislaus River	1B,2,3,7,8,9,13,19,21	X		X	X
Lower San Joaquin River	1B,2,3,8,9,21	X			X
<b>Sacramento-San Joaquin Delta</b>	1B,2,3,4,5,14,15,21	X	X		X

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<sup>a</sup> From RBDD upstream to Keswick Dam

<sup>b</sup> Below RBDD

3406(b)(16), 3406(b)(18), and 3406(b)(22) are not relevant.

3406(b)(3) and (b)(21) could occur on any river.

3406(b)(1B), (b)(2), and (b)(8) could occur on CVP rivers only.

3406(b) provisions are as follows:

- 1B. Modify CVP operations
  2. Manage 800,000
  3. Supplemental water
  4. Tracy pumping plant
  5. Contra Costa pumping plant
  6. Shasta temperature control
  7. CVP flow standards
  8. Pulse flows
  9. Flow fluctuations
  10. RBDD
  11. Coleman Hatchery
  12. Clear Creek
  13. Gravel and Riparian
  14. Delta Cross Channel
  15. Old River Basin
  17. ACID Diversion Dam
  19. Carryover storage
  20. GCID pumping plant
  21. Fish screens
  22. Enhance wildlife habitat (see Appendix A)
  23. Trinity River (to be covered separately)
-

Table 4-3. AFRP (Section 3406 (b)(1)) Categories of Actions by Watershed

Stream Section	Water Management Modifications							Structural Modifications					Habitat Restoration										Screens	
	Additional Flows	Pulse Flows/ Timing Strategies	Purchase Water/ Water Rights	Add'l Water Sources	Temp. Control	Reservoir Mgmt	Curtail Delta Water Exports	Ladders Replem/ Repair Instal'n	Barrier/ Siphon Instal'n	Small Dam/ Diversion Removal	Diversion Reductions/ Closure	Gravel Rehab Replm't	Restric/ Modify Gravel Mining	Water Quality	Stream Channel Rehab/ Modification	Riparian Rehab/ Protect	Erosion Control	Stream Fencing	Watershed Mgmt Planning	Predator Control	T&E Species Rehab	Fish Screens		
Upper Mainstem Sacramento River	X	X	X	X	WM			X	X		X	X	X	X	X	X						X		
Clear Creek	X		X		WM			X	X	X		X	X			X	X		X					
Bear Creek	X		X									X	X									X		
Battle Creek	X							X	X		X										X	X		
Antelope Creek	X		X												X									
Mill Creek										X		X			X	X			X					
Deer Creek	X		X		H							X				X			X					
Big Chico Creek		X		X	H			X	X			X			X	X								
Miscellaneous Streams	X		X	X					X					X		X								
Feather River	X	X			WM							X			X					X				
Bear River	X				WM				X					X								X		
Mokelumne River	X	X			WM			X		X		X		X	X	X		X		X		X		
Calaveras River	X		X		WM	X		X	X	X												X		
Merced River	X	X	X	X	WM	X	X	X	X			X		X	X	X	X	X	X	X		X		
Stanislaus River	X	X	X	X	WM,S	X	X	X		X		X		X	X	X	X	X	X	X		X		
Sac-San Joaquin Delta	X				WM		X				X				X	X						X		

- Notes:
- (1) Temperature control can fall into water management (WM), structural (S), or habitat restoration (H) categories depending on the specific temperature control mechanism.
  - (2) The following AFRP actions do not fit into the four action categories and are not shown: regulations, protection, and law enforcement; disease control; and genetic diversity.
  - (3) The Upper mainstem Sacramento River is from RBDD to Keswick Dam.

Source: modified into action categories from U.S. Fish and Wildlife Service, Anadromous Fisheries Restoration Program Table.

## Conceptual Monitoring Design

This section discusses conceptual-level sampling design considerations and offers general suggestions. It is important to emphasize, however, that CAMP will not influence the priority or scheduling of any restoration actions. Restoration actions will be implemented based on priority needs, funding availability, permit acquisition, and completion of any required environmental documents. Consequently, CAMP will necessarily be "adaptive monitoring" and will not influence restoration action implementation. Sampling design considerations and suggestions discussed below, however, will be followed where practical and appropriate.

### Sampling Design Considerations

The value of a monitoring plan for determining the relative effectiveness of the four action categories depends on how well the design meets several prerequisites for an optimal sampling design. Green (1979) emphasized the need for controls in both space and time to effectively detect or measure the effect of a given treatment on a response variable. For CAMP, spatial control would be achieved by sampling juvenile populations in the test watersheds or reaches where a specific action is implemented and in a control watershed or reach that is similar to the test reaches except for the absence of the action being evaluated. If spatial control is lacking and only pre- and post-action data are available from the test watershed, a significant change in juvenile production could occur that is unrelated to the action. Without spatial control, the potential cause of the change could not be identified. Temporal control would be achieved by collecting baseline data from the test and control areas before the action is implemented. If temporal control is lacking, differences in juvenile production that existed between the test and control areas before the action is implemented would go undetected, thereby biasing any conclusions regarding the magnitude of the differences attributable to the action categories.

Providing adequate controls presents the most difficult challenge in evaluating the four action categories. Adequate baseline data often are not available to evaluate differences in juvenile production between potential test and control reaches or streams before an action is implemented. In such cases, temporal control will be lacking and any changes in juvenile production attributable to a given action can only be inferred by comparing these changes to changes in juvenile populations at a suitable control area. In many cases, suitable control reaches or streams do not exist because of the confounding influences of environmental factors that interact with the factors (that are directly influenced by the action being evaluated) that already or indirectly affect the response variable (e.g., juvenile production) among reaches and streams. For example, the effectiveness of a new fish ladder is comparatively easy to measure by estimating the number of fish migrating up the ladder, spawning in previously unavailable habitats, and contributing to adult population increases over time. In contrast, the effects of water management modifications and habitat restoration actions are dependent on many interdependent factors and are much more difficult to isolate and assess because of their potential interaction with other uncontrolled variables that affect production (e.g., predation). Additionally, evaluation of water management modifications will be hindered by substantial annual

variability in hydrologic conditions that will obscure (and at times dwarf) the effects of water management actions implemented for anadromous fish.

The ability to detect differences in the effectiveness of actions will therefore depend on the degree to which confounding environmental factors and major sources of data "noise" can be controlled or standardized between test and control streams and test and control time periods. Based on our current knowledge of the biological and environmental characteristics of potential monitoring streams identified by CAMP, it appears that the conditions for establishing effective spatial and temporal controls will seldom be available. CAMP will need to be flexible and incorporate the concept of "adaptive monitoring", whereby monitoring is adjusted as restoration actions are implemented.

### General Suggestions

Several general monitoring designs based on some of the desired characteristics for CAMP's monitoring of the effectiveness of the four action categories are discussed below. The specific AFRP Restoration Plan will provide greater detail on the actual categories of actions to be implemented, the location of implementation, and the location and characteristics of monitoring of specific actions. These factors are important for developing CAMP's Implementation Plan. More importantly for CAMP, however, will be the actual funding, permitting, and implementation of specific actions, which may vary considerably from the AFRP Restoration Plan. CAMP will need to be opportunistic in how it incorporates these actions into its overall program.

Clear Creek offers an example of a potential opportunity for comparing different restoration actions. Section 3406(b)(12) requires flows from Whiskeytown Dam to allow sufficient spawning, incubation, rearing, and outmigration for salmon and steelhead *after* Clear Creek has been restored and a new fish ladder has been constructed at McCormick-Saeltzer Dam. Consequently, evaluations of the relative effectiveness of structural, habitat modification, and water management actions could be accomplished if ladder construction, habitat restoration, and flow modification are temporarily isolated and the population response assessed during separate time periods. Although the independent effects of these actions cannot be quantified with this approach, the relative change in juvenile populations following implementation of each action would provide insight into the contribution of each action in restoring salmon and steelhead populations. The advantage of this opportunity is that factors that can confound comparisons between different streams (e.g., regulated versus nonregulated streamflows) can be controlled. The applicability of this approach, however, will depend on the time frame for implementing the restoration actions.

Some upper Sacramento River tributaries do not currently support fall-run chinook salmon but are expected to regain populations following implementation of CVPIA actions. Some of these marginal or nonproductive streams differ in ranking of potential limiting factors for chinook salmon

success, and those differences may be used to elucidate the effectiveness of individual actions. For example, Cow and Bear creeks have few spawning fall-run chinook salmon under most water conditions, and are assumed to be limited by a combination of low flows and losses to unscreened diversions. Screens and minimum flows are suggested for habitat improvements for these streams. In contrast, passage issues are paramount at Elder, Thomes, and Stony creeks, which currently support few spawning fall-run chinook salmon. Fish passage around the Corning Canal siphons and GCID canal should open these streams. In combination with watershed management to control sedimentation and guaranteed instream flows, these creeks are expected to regain fall-run chinook spawning runs. In this example, structural modifications to repair channel blockage (latter three streams) could be compared to diversion screening and guaranteed flows (former two streams) for their effects on juvenile salmon production. The quantification of effects on juvenile salmon production are greatly improved for these streams by the lack of or low current production.

The major San Joaquin tributary streams, the Tuolumne, Merced, and Stanislaus rivers, may require all four general categories of improvements as CVPIA actions. However, flows have been identified as the primary factor affecting salmon populations in these streams and new flow schedules are proposed for all three streams. Monitoring of juvenile salmon populations before and after implementing new minimum flows during May and June may indicate the relative importance of water management for these tributaries. Differences in juvenile salmon production in these streams, before and after water management modifications and before and after any other structural or habitat restoration, can be used as relative measures of effectiveness of the categories of actions.

## CONCLUSIONS

The CAMP Project Team believes that the AFRP Restoration Plan could provide important information to facilitate development of specific monitoring prescriptions in CAMP's Implementation Plan for evaluating the effectiveness of the four action categories. Even more important will be the actual implementation of actions. Until more information is available, designing a specific monitoring program to evaluate the effectiveness of the four action categories will be constrained to the general and conceptual level defined herein. The above examples illustrate the manner in which differences between test and control watersheds and before and after comparisons within these watersheds may be used to elucidate the effects of broad categories of CVPIA actions on juvenile salmon production. The individual evaluations will be location-specific, but the accumulation of numerous action-specific monitoring results over time as increasing numbers of actions are implemented will produce general information on the relative importance of action categories in enhancing fall-, winter-, and spring-run chinook salmon and striped bass production. The monitoring results and evaluation of the effectiveness of action categories will need to be long term, continuously updated, and fully integrated. Additionally, a major focus of CAMP will be to anticipate and take advantage of unique opportunities that will arise for evaluating the effectiveness of action categories.



## Conceptual Monitoring Program

## **Chapter 5. Conceptual Monitoring Program**

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### **INTRODUCTION**

This chapter describes several levels of alternative conceptual monitoring programs for meeting CAMP's primary goal of assessing the overall (cumulative) effectiveness of actions implemented under Section 3406(b) in meeting systemwide population goals, and describes general considerations and guidelines for meeting CAMP's secondary goal of assessing the relative effectiveness of each of the broad action categories in meeting these goals. This chapter builds on the goals, concepts, guidelines, monitoring programs, and constraints identified for CAMP in previous chapters. The conceptual monitoring program is intended to provide general conceptual frameworks from which the specific elements of individual monitoring programs can be developed, defined, prioritized, and redefined by the Service. The program for CAMP Goal #2 is much less specific than for CAMP Goal #1 because of uncertainty concerning many of the details of the specific AFRP actions and monitoring programs.

The conceptual monitoring program will need to be dynamic, flexible, adaptable, and opportunistic as it is further developed into CAMP's Implementation Plan. Short-term monitoring programs over the next 10 years will be rapidly designed and deployed. The information generated from these action-specific and other short-term monitoring programs will provide critically important data for CAMP. It is quite likely that the direction of CAMP could change several times in the next 10 years to respond to the short-term programs at hand, but then stabilize into a consistent, rather than opportunistic, assessment program for the remaining years.

The program has been designed so that assessments are conducted not only in major tributaries, but in the mainstem Sacramento and San Joaquin Rivers and the Delta. Target species for accomplishing Goal #2 will ensure that major limiting factors in a wide geographic area will be addressed within the four action categories.

### **PROGRAM FOR ASSESSING OVERALL EFFECTIVENESS OF ACTIONS IN DOUBLING POPULATIONS (CAMP GOAL #1)**

#### **General Overview**

This section builds primarily on Chapter 3, which describes species-specific monitoring goals, population assessment methods employed during the 1967-1991 baseline period, potential revisions

to existing methods, and monitoring needs. For each anadromous species, this chapter sets forth recommended, high-level, and low-level conceptual monitoring programs defined as follows:

- the recommended conceptual monitoring programs provide the necessary long-term monitoring data to reasonably meet CAMP's primary goal;
- the high-level conceptual monitoring programs provide additional or alternative study designs and methods that are not critical in meeting CAMP needs, but that would provide a much stronger scientific or analytical basis for meeting CAMP's primary goal; and
- the low-level conceptual monitoring programs identify ways to reduce costs of the recommended monitoring programs, but always with substantial reductions in the accuracy and precision of the resulting data and population estimates.

By considering each level of potential monitoring, the Service can best evaluate the potential monitoring alternatives and select species-specific approaches on which the CAMP Implementation Plan can be developed in Phase II. There is no prioritization of the elements included for each recommended program, however, because each element is considered to be essential to meet CAMP's primary goal of long-term population monitoring to evaluate the overall effectiveness of CVPIA action Section 3406(b) actions. The high-level conceptual monitoring programs, while not determined to be necessary to meet CAMP needs, provide additional data needs that could be funded through other CVPIA elements or fisheries programs.

The species-specific programs described below must be sufficient to monitor populations on a "long-term" basis. AFRP specifies that the long term, in this context, must encompass at least several generations of fish (not less than five) over a variety of hydrologic conditions (to allow for natural variation in production) and will continue indefinitely (U.S. Fish and Wildlife Service 1995). Based on this guidance, CAMP proposes that monitoring continue for 25-50 years after all Section 3406(b) restoration actions are implemented or until it is determined that sustainable natural production of fish at not less than twice the average levels attained during 1967-1991 has been achieved. The doubling goals, if they are to be attained, will likely be attained within this time frame for chinook salmon, steelhead trout, striped bass, and American shad. An implicit assumption here is that it may take 25 years to increase populations to doubling goals, and then another 25 years to *average* doubling goals on a long-term basis. Programs for white sturgeon and green sturgeon are recommended for 50-100 years, or longer, because of the species' longevity. Table 5-1 summarizes elements of CAMP's recommended monitoring programs by species and watershed. Program elements that are not currently funded for 1996 are also identified.

It is envisioned that basic data analysis will occur annually to identify emerging trends with target populations. More intensive data analyses will occur less frequently (every 5 years). After review of these analyses by a designated committee of experts, recommendations will be made concerning adjustments to the program.

Table 5-1. Summary of Recommended Monitoring Programs by Species and Watershed to Meet CAMP Goals

Watershed	Chinook Salmon (all races)						Steelhead Trout				Striped Bass	American Shad	White and Green Sturgeon
	Spawning Escapement Surveys	Hatchery Counts	Develop Alternative Population Estimation Procedure	Angler Surveys	Ocean Harvest Sampling	Coordinated Hatchery Marking Program	Ladder Counts	Hatchery Counts	Angler Surveys	Coordinated Hatchery Marking Program	Mark-Recapture Program	Midwater Trawl Surveys	Mark-Recapture Program
Sacramento River	R,E	N	R,U	R,U	N	N	E	N	R,U	N	N	N	N
Feather River	R,E	R,E	N	R,U	N	R,U	N	E	N	R,U	N	N	N
American River	R,E	R,E	N	R,U	N	R,U	N	E	N	R,U	N	N	N
Yuba River	R,E	N	N	R,U	N	N	N	N	N	N	N	N	N
Tuolumne River	R,E	N	N	R,U	N	N	N	N	N	N	N	N	N
Battle Creek	R,E	R,E	N	R,U	N	R,U	N	R,E	N	R,U	N	N	N
Stanislaus River	R,E	N	N	R,U	N	N	N	N	N	N	N	N	N
Merced River	R,E	R,E	N	R,U	N	R,U	N	N	N	N	N	N	N
Mokelumne River	R,E	R,E	N	R,U	N	R,U	N	E	N	R,U	N	N	N
Mill Creek	R,E	N	N	N	N	N	R,U	N	N	N	N	N	N
Deer Creek	R,E	N	N	N	N	N	R,U	N	N	N	N	N	N
Butte Creek	R,E	N	N	N	N	N	N	N	N	N	N	N	N
Delta	N	N	N	R,U	N	N	N	N	N	N	R,U	R,E	R,U
Ocean	N	N	N	N	R,E	N	N	N	N	N	N	N	N

R = Recommended program.

E = Existing program.

N = Not applicable or not recommended.

U = Program funded until June 30, 1996.

? = Program funding for 1996 uncertain.

## Chinook Salmon

### Recommended Program

The recommended program for accurately assessing achievement of the chinook salmon restoration goals is to:

- continue the use of the Schaefer method for estimating annual spawning escapement indefinitely (, Feather River, Yuba River, American River, Battle Creek, Mill Creek, Deer Creek, Butte Creek, Tuolumne River, Stanislaus River, Merced River, and Mokelumne River);
- continue annual counts of adult returns to all Central Valley salmon and steelhead hatcheries;
- develop or intensify alternative population estimation procedures to estimate upper Sacramento River chinook salmon runs, including electronic technology (e.g., hydroacoustics) and mark-recapture techniques in conjunction with angler surveys;
- continue and expand annual angler survey programs to include all reaches and streams where significant sport fisheries exist;
- continue the annual ocean commercial and sport fishery sampling program; and
- develop a coordinated chinook salmon constant fractional marking program at appropriate Central Valley salmon hatcheries.

The above programs that were implemented during the 1967-1991 baseline period would be continued, but several additional studies are considered necessary to address some of the deficiencies and weak assumptions that were necessarily used to develop the AFRP chinook salmon restoration goals. The existing programs for chinook salmon are described in detail in Chapter 3.

**Unmet Needs.** DFG funding for determining spawning escapement has been cut in recent years, and annual funding can be quite variable. Without the continued funding of the ongoing sampling programs for chinook salmon, there will be no comparable data to evaluate whether chinook salmon are being doubled on a long-term basis. In addition, no other species is sufficiently similar to the chinook salmon races to serve as an indicator for evaluating whether CVPIA actions are effectively doubling the four chinook salmon races. Because chinook salmon is a target species for CVPIA, and no other indicator species can be used for chinook salmon, continued sampling for chinook salmon is necessary to meet CAMP goals. Continued funding of Schaefer population estimates at least in the 11 major chinook salmon rivers is considered to be high priority because there is no existing program in place that will collect similar data. The need to continue this sampling program is even more imperative because three races of chinook salmon have been selected as

indicators for meeting CAMP's second goal of evaluating the long-term effectiveness of the four action categories.

Additional unmet needs include developing or intensifying alternative population estimation procedures to estimate upper Sacramento River chinook salmon runs, continuing and expanding angler survey programs to include all reaches and streams where significant sport fisheries exist, and developing a coordinated chinook salmon marking program at appropriate Central Valley salmon hatcheries. All of these monitoring needs are currently unfunded. These programs meet some of the basic CAMP needs for effectively monitoring natural production of chinook salmon and also provide basic needs for many other programs and agencies.

**Continuing and Expanding the Use of the Schaefer Method for Estimating Spawning Escapement.** The AFRP goals for doubling chinook salmon populations require an extensive monitoring program; population estimates from more than twenty streams were combined to develop the chinook salmon production goal of 990,000 fish (U.S. Fish and Wildlife Service 1995). Other anadromous species have population goals that were established at a single geographic location. Although CAMP must be comprehensive and broad in scope, funding constraints may make it impossible to implement long-term monitoring programs for chinook salmon on every target stream in the Central Valley. This is especially true for fall-run chinook salmon, which are broadly distributed and segregated into relatively distinct runs or spawning populations. To meet the objective of systemwide coverage, while remaining within budgetary constraints, monitoring efforts should be concentrated in those streams that can provide the most information per sampling dollar. The value of monitoring a selected subset of runs versus less intensive monitoring of all target watersheds is a key consideration in developing a cost-effective monitoring program.

The recommended monitoring program for chinook salmon involves a hierarchical approach that minimizes the cost and effort required to meet CAMP Goal #1 without sacrificing significant amounts of information:

1. Streams are prioritized according to their relative or potential contribution to total salmon production.
2. Indicator streams are used to represent other streams or broader geographic areas to reduce the extent of monitoring efforts needed to evaluate overall abundance trends.
3. Monitoring costs and efforts are further reduced by sampling specific streams using index reaches and/or at less frequent intervals.

**Prioritizing Streams.** Based on average annual spawning escapement estimates of fall-run chinook salmon by watershed during the 1967-1991 baseline period, 96% of total Central Valley spawning escapement is attributable to nine streams ( Table 5-1). These streams, in order of decreasing percent contribution, are the mainstem Sacramento River (38%), Feather River (21%), American River (16%), Yuba River (6%), Tuolumne River (4%), Battle Creek (4%), Stanislaus River (2%), Merced River (2%), and Mokelumne River (1%). Prioritization within these streams is extremely difficult as they are all important contributors to Central Valley or to smaller but important geographic areas within the Central Valley. Prioritization could be conducted simply based on their

Table 5-2. Relative Contribution of Watersheds to the Total  
Sacramento-San Joaquin Fall-Run Chinook Salmon Escapement Estimate

Rank	River or Stream	Average Spawners	CVP Stream	NonCVP Stream	Cumulative Total	Percentage of Total	Cumulative Percentage
1	Sacramento River	76,701	76,701		76,701	38.41	38.41
2	Feather River	41,003		41,003	117,704	20.53	58.94
3	American River	32,307	32,307		150,011	16.18	75.12
4	Yuba River	12,868		12,868	162,879	6.44	81.57
5	Tuolumne River	8,923		8,923	171,802	4.47	86.03
6	Battle Creek	8,369		8,369	180,171	4.19	90.23
7	Stanislaus River	4,807	4,807		184,978	2.41	92.63
8	Merced River	4,035		4,035	189,013	2.02	94.65
9	Mokelumne River	2,553		2,553	191,566	1.28	95.93
10	Cottonwood Creek	1,647		1,647	193,213	0.82	96.76
11	Clear Creek	1,584	1,584		194,797	0.79	97.55
12	Cow Creek	1,373		1,373	196,170	0.69	98.24
13	Mill Creek	1,104		1,104	197,274	0.55	98.79
14	Cosumnes River	764		764	198,038	0.38	99.17
15	Butte Creek	418		418	198,456	0.21	99.38
16	Deer Creek	406		406	198,862	0.20	99.59
17	Miscellaneous	304		304	199,166	0.15	99.74
18	Big Chico Creek	242		242	199,408	0.12	99.86
19	Antelope Creek	192		192	199,600	0.10	99.95
20	Paynes Creek	90		90	199,690	0.05	100.00

percent contribution to chinook salmon spawning escapements. These streams also support the bulk of the inland sport fishery for chinook salmon and include all streams with major salmon hatcheries. Consequently, intensive monitoring efforts will be required on these streams to accurately estimate annual harvest, spawner abundance, and the proportion of naturally produced and hatchery-produced fish.

The potential to increase stocks in river systems, as well as information on historic spawning escapements during the 1967-1991 baseline period, is important to prioritize streams for monitoring. All of the rivers mentioned above, including Clear, Butte, Mill, and Deer creeks, but excluding the Feather, American, and Yuba rivers have high priorities for restoration activities. The Feather, American, and Yuba rivers comprise a major component of the overall salmon production, however, and should still be monitored. These rivers could also serve as excellent control streams if restoration actions are delayed or not as extensive in these three watersheds.

The nine major salmon production streams are broadly distributed throughout the Central Valley and would likely provide good indicators of the status of fall-run chinook salmon runs in their respective geographic areas and for the basin as a whole to achieve CAMP's long-term goal. Additionally, continued monitoring efforts on the mainstem Sacramento River would provide abundance estimates and angler catch data for late fall-, winter-, and spring-run chinook salmon. Monitoring fall-run chinook salmon in Battle Creek could be extended to include late fall-run chinook salmon. In addition to these streams, Deer and Mill Creeks should be included as primary monitoring streams for spring-run chinook salmon because of the unique genetic status of these populations. Butte Creek shows great restoration potential, is a primary spring-run chinook salmon stream, and has a major program of restoration actions proposed in its watershed; for these reasons, Butte Creek should be added to the streams above, making a total of 12 streams that should be monitored on an annual basis. Cow, Antelope, and Big Chico creeks, identified by DFG as high-priority spawning areas, added little to meeting the overall doubling goals and were not deemed necessary for meeting CAMP Goal #1. However, monitoring adult chinook salmon populations could be implemented in the future on these and other tributaries for meeting CAMP Goal #2.

**Using Indicator Streams.** AFRP's objective is to double the natural production of all species and races of anadromous fish in specific streams and to preserve genetic stocks. If this proves infeasible, the unmet production increment will be transferred to other streams in the following order of priority:

1. another stream in the same drainage system;
2. another stream within the larger basin, such as the Sacramento River basin; and
3. any stream within the Central Valley.

Not included in the list of primary monitoring streams identified above are at least 15 streams that collectively account for about 2% of the total average annual escapement during the baseline period. In view of the AFRP objective of doubling natural production in individual streams to the extent possible, some level of monitoring of these streams is desirable, especially considering that the runs they support may have historically maintained a higher degree of genetic isolation from hatchery stocks than runs on major tributaries. Because monitoring these streams would add substantially to

overall monitoring budgets and effort, however, the use of indicator streams was examined as a means to minimize the amount of monitoring needed on these streams.

To identify potential indicator streams, Pearson correlation coefficients were calculated for all possible pairwise combinations of streams for which annual escapement estimates were available for the 1967-1991 period (Appendix C, Table C-1). (Specific analysis methods are presented in Appendix C.) Significant positive relationships were found between fall-run chinook salmon escapement in Cow and Cottonwood creeks, fall-run chinook salmon spawning escapement in Paynes Creek and several smaller miscellaneous creeks, fall-run chinook salmon spawning escapements in the Tuolumne and Stanislaus rivers, and spring-run chinook salmon escapement in Mill and Deer creeks. Cow Creek, Paynes Creek, Mill Creek (or Deer Creek), and the Stanislaus River could be used as indicators of the other respective streams if CVPIA or other watershed actions consistently affect both of any paired set of watersheds. If index watersheds are pursued further, additional investigation of the independence of each paired stream's population estimate will be necessary to ensure that one stream's population estimates are not based in some way on estimates from another stream.

**Using Index Reaches and Larger Sampling Intervals.** The degree to which monitoring of salmon abundance in one stream can be used to assess trends in other streams depends on the strength of the relationship and whether the relationship persists in the future. Consequently, any environmental changes or restoration actions that differentially affect such populations in the future have the potential of altering these relationships and reducing the utility of an indicator stream. A minimal monitoring effort, involving index reaches and/or less frequent sampling, may be warranted to verify the persistence of these relationships or confirm abundance trends in otherwise non-monitored streams. For example, key spawning or summer holding reaches in specific tributaries could be defined and surveyed two to three times during the spawning season every other year. Counts of adult salmon or carcasses in these reaches could be compared to escapement estimates in adjacent streams or used to detect changes in abundance over time. Such surveys may be warranted for smaller tributaries not included among the monitoring streams identified by DFG. It is noted, however, that sampling at intervals less than annually may not provide data necessary for other programs and could be difficult to staff.

**Continuing Counts of Adult Returns to all Central Valley Salmon and Steelhead Hatcheries.** An excellent database exists for adults returning to Central Valley hatcheries. The collection of these data is relatively easy and should be continued, particularly if a consistent fraction of hatchery fish is marked.

**Developing or Intensifying Alternative Population Estimation Procedures to Estimate Upper Sacramento River Chinook Salmon Runs.** Direct counts of upstream migrating fall-, late fall-, winter-, and spring-run chinook salmon have been available since 1967. The recent and future practice of raising RBDD's gates eliminates a highly effective counting station for late fall-run chinook salmon and compromises the counting of the other three races. The feasibility of using electronic technology (e.g., hydroacoustics) should be investigated as well. Alternative population estimation procedures, probably involving an expanded angler survey program in the mainstem Sacramento River above RBDD, will be necessary.

**Continuing and Expanding Angler Survey Programs to Include all Reaches and Streams Where Significant Sport Fisheries Exist.** Continuing and expanding the angler survey program initiated by DFG in 1991 would provide comprehensive monitoring of inland sport harvest of chinook salmon, as well as other species, on a long-term basis. At a minimum, high priority reaches such as the mainstem Sacramento River, American River, Feather River, Yuba River, and mainstem San Joaquin River could be sampled. These estimates of inland sport harvest are important in developing the systemwide estimates of in-river chinook salmon populations. Sampling the mainstem Sacramento River becomes even more important with the loss of direct counts at RBDD.

**Continuing Ocean Commercial and Sport Fishery Sampling Program.** Monitoring ocean commercial and sport harvests of chinook salmon is an essential element of CAMP monitoring efforts because of the substantial portion of adult production represented by this harvest. The currently used assumption of equal harvest rates among stocks is tenuous at best, as described in Chapter 3. The stock-specific goals established by the AFRP necessitate improved estimates of the contribution of individual salmon stocks to the ocean fishery. In conjunction with the recommended hatchery marking program, monitoring of ocean commercial and sport harvests becomes of even greater importance.

**Developing a Coordinated Chinook Salmon Marking Program at all Central Valley Salmon Hatcheries.** A systematic and coordinated chinook salmon marking program has never been attempted for chinook salmon in the Central Valley. Such a program is essential to provide better information on the ratio of naturally produced and hatchery-produced chinook salmon stocks. The lack of this type of program has compromised the ability to most accurately establish and then monitor natural production of chinook salmon in the Central Valley. CAMP could be conducted without a chinook salmon marking program, just as AFRP set restoration goals for chinook salmon without such a program. It would be extremely desirable, however, to have a systematic and coordinated marking program to provide greater precision and accuracy to the systemwide estimates of chinook salmon production. This type of marking program also provides additional information that goes well beyond simply assisting in more accurately determining the number of naturally produced and hatchery-produced chinook salmon; a number of basic management, ecological, and population dynamic principles could be evaluated with a well-designed program.

A marking program for naturally produced salmon, integrated with the program for marking hatchery fish, would provide additional and valuable information but is not recommended at this time because of the additional costs for capturing and recapturing a sufficient sample size to yield meaningful results.

### **High-Effort Program**

An intensive CAMP monitoring program for chinook salmon would entail implementing long-term annual monitoring programs on every target stream and for every race in the Central Valley. Such a program would require expanding the use of methods for estimating total spawner abundance (e.g., mark-recapture techniques) to those streams not included in the list of primary monitoring streams identified above. These additional streams would include all of the streams identified in the

AFRP Working Paper, as well as those identified by DFG (1995a) as medium and low priority for monitoring spawner escapement, inland harvest, and recovery of CWT fish. Those streams for which adequate baseline population data are not available (e.g., Thomes Creek and other western Sacramento River tributaries) could also be included to monitor future abundance trends. This additional sampling is not needed on an annual basis to meet the long-term needs of CAMP. However, it would be beneficial to conduct this high-effort program every 5-10 years to get a comprehensive snapshot of escapement estimates throughout the Central Valley. This type of information would be useful in evaluating systemwide, but specific trends in chinook salmon populations, as well as verifying relationships between chinook salmon abundance between similar watersheds described previously.

A marking program for naturally produced salmon, integrated with the program for marking hatchery fish, could be implemented to provide additional and valuable information. This program would require additional and substantial costs for capturing and recapturing a sufficient sample size of chinook salmon to yield meaningful results.

The usefulness of the Jolly-Seber and Schaefer methods has been debated for many years. Additional research regarding the performance of the two methods for application in different-sized streams would be helpful, but not necessary, in meeting CAMP's long-term goals. Even if this type of research is conducted, however, the existing 1967-1991 database is composed almost entirely of Schaefer estimates, which should continue to serve as the basis for evaluating the success of CVPIA Section 3406(b) actions at this time. Without definitive information that the Jolly-Seber method, or any other readily available method, is substantially more accurate than the currently used modified Schaefer method, the modified Schaefer method should continue to be employed.

### **Low-Effort Program**

Any low-effort program should not compromise the sampling gear and protocol that were instituted during the 1967-1991 period. Theoretically, these parameters could be reduced, but population estimates relative to the baseline period would likely be seriously compromised.

The minimum level of effort needed to meet CAMP objectives would entail continued monitoring of chinook salmon spawner escapement in the 11 primary monitoring streams, all Central Valley hatchery returns, ocean commercial and sportfishing harvest, and the inland sport harvest. Index watersheds could not be effectively used among the 11 primary monitoring streams, with the possible exception of the Tuolumne and Stanislaus rivers. The loss of RBDD counts necessitates comprehensive angler surveys in the mainstem Sacramento River above RBDD, even though such monitoring is not currently conducted.

The frequency of sampling could also be reduced. Sampling biennially (every other year) could meet CAMP's primary objective of evaluating whether anadromous fish are doubled *on a long-term basis* over the course of 25-50 years. This reduced sampling effort was not recommended simply because of the importance of chinook salmon for ecologic, scientific, economic, and social reasons. Many chinook salmon research and management programs depend on the availability of chinook

salmon population estimates on a consistent (and annual) basis. In addition, the effectiveness of the numerous tagging programs would be reduced because the number of potential recaptures would be cut in half with biennial sampling.

## **Steelhead**

### **Recommended Program**

The recommended program for accurately assessing achievement of the steelhead restoration goal is to:

- continue adult counts on Mill and Deer creeks,
- continue adult counts at Coleman National Fish Hatchery,
- develop a comprehensive angler survey program on the Sacramento River to accurately and precisely estimate angler harvest to generate estimates of adult steelhead passing RBDD,
- continue to calculate the number of hatchery-produced steelhead that spawned naturally as 29% of the total natural escapement and sportfishing harvest, and
- develop a coordinated steelhead constant fractional marking program at appropriate Central Valley hatcheries.

Existing methods used during the 1967-1991 baseline period should be followed to the extent possible in future sampling efforts. The existing program is described in detail in Chapter 3.

**Unmet Needs.** DFG funding for continuing the existing angler survey program on the Sacramento River that is necessary to obtain steelhead population estimates has been eliminated for 1996. To exacerbate this problem, RBDD steelhead counts will be unavailable whenever the RBDD gates are raised, which will likely encompass the primary steelhead upstream migration periods. Without the continued funding of the ongoing angler survey program on the mainstem Sacramento River, there will be no other comparable methods that will provide the necessary data to evaluate whether steelhead populations upstream of RBDD are being doubled on a long-term basis. In addition, no other species is sufficiently similar to steelhead to serve as an indicator for evaluating whether CVPIA actions are effectively doubling steelhead populations. Because steelhead is a target species for CVPIA, and no other indicator species can be used for steelhead trout, continued and expanded angler surveying for steelhead is considered to be of high priority because there is no other program in place that will collect similar data.

A thorough angler survey program on the Sacramento River upstream of RBDD must be developed to evaluate whether steelhead goals at RBDD are being met. Because of several problems

with the existing relationship between annual steelhead populations passing RBDD and steelhead harvest (see Chapter 3 for details), additional data analyses will be required to develop a new relationship between harvest and steelhead abundance passing RBDD that is more accurate than previous methods but also allows comparability with 1967-1991 baseline data.

The recommended program for steelhead also would involve reducing the number of assumptions that must currently be made to arrive at steelhead population estimates at RBDD, or at least providing additional data to test these assumptions. A constant fractional steelhead marking program implemented at all steelhead-producing Central Valley hatcheries would substantially reduce the number of assumptions currently necessary to determine abundance estimates for steelhead.

### **High-Effort Program**

A whole host of additional studies could be conducted, to reduce the number of assumptions that are used to estimate steelhead populations. Intensive angler surveys could be specifically designed to evaluate the numeric assumptions that were used by AFRP to estimate naturally produced steelhead abundance. While not directly tied to evaluating whether the single AFRP steelhead goal at RBDD is being met, broader estimates of steelhead abundance in key geographic watersheds would be highly desirable. The current goal, for instance, does not address attempts to reestablish steelhead populations in the San Joaquin River watershed or does not consider important steelhead populations in the Yuba River. Providing this type of information would be costly and not directly related to evaluating AFRP's steelhead goal at RBDD. If AFRP provided additional steelhead goals in the future, however, CAMP may need to be adjusted to address such goals.

### **Low-Effort Program**

Any low-effort program should not compromise the sampling gear, locations, and protocol that were instituted during the 1967-1991 period. The unmet needs described above for the recommended program must be part of the low-effort program as well if CAMP's goal of evaluating long-term steelhead abundance is to be met. Consequently, the low-effort program is essentially the same as the recommended program. Monitoring steelhead populations on Deer and Mill creeks could be discontinued as these efforts are not directly related to evaluating the RBDD steelhead goal, but the counts are already made for chinook salmon and provide two of the best population estimates of steelhead trout in the Central Valley. The magnitude of the hatchery marking program and subsequent angler surveys could also be limited or reduced in scope to meet any budgetary constraints.

The frequency of sampling could also be reduced. Sampling biennially could meet CAMP's primary objective of evaluating whether anadromous fish are doubled *on a long-term basis* over the course of 25-50 years. The effectiveness of any existing or future steelhead tagging program would be reduced, however, because the number of potential recaptures would be cut in half with biennial sampling. Steelhead trout population estimates are already relatively poor in quality compared to other anadromous species, and the existing program *prior* to funding cuts represented the low-effort

program. For these reasons, a low-effort program is not recommended because such a program will jeopardize the ability to reasonably meet CAMP's goal of evaluating whether steelhead populations are doubled.

## **Striped Bass**

### **Recommended Program**

The recommended program for accurately assessing achievement of the striped bass restoration goal is to:

- continue the existing mark-recapture program for adult striped bass and
- continue current calculation of adult population estimates.

These programs would be continued in the same manner as they were conducted during the 1967-1991 baseline period. Tagging efforts should be conducted biennially, along with the annual angler survey, to provide adequate monitoring. The existing program is described in detail in Chapter 3.

**Unmet Needs.** DFG funding for continuing the mark-recapture sampling that is necessary to obtain striped bass population estimates has been eliminated for activities past June 30, 1996. Without the continued funding of the ongoing sampling programs for striped bass, there will be no other comparable methods that will provide the necessary data to evaluate whether striped bass populations are being doubled on a long-term basis. In addition, no other species is sufficiently similar to striped bass to serve as an indicator for evaluating whether CVPIA actions are effectively doubling striped bass populations. Since striped bass is a target species for CVPIA, and no other indicator species can be used for striped bass, continued sampling for striped bass is necessary to meet CAMP goals. Continued funding of the existing striped bass mark-recapture program is considered to be of high priority because there is no other program in place that will collect similar data. The need to continue this sampling program is even more imperative as striped bass has been selected as an indicator species for meeting CAMP's second goal of evaluating the long-term effectiveness of the four action categories in the Delta.

### **High-Effort Program**

A high-effort program could serve to improve the precision and accuracy of adult striped bass population estimates. The current mark-recapture program could be intensified by increasing sampling locations, periods, and effort. Tagging efforts could be conducted on an annual basis rather than biennially to improve population estimates. Tagging and recovery efforts could be increased to provide greater sample sizes and, therefore, potentially more precise and accurate population estimates. Additional monitoring locations could be sampled, but this sampling is less desirable than increasing existing efforts at previously sampled locations.

## **Low-Effort Program**

Any low-effort program should not compromise the sampling gear, locations, and protocol that were instituted during the 1967-1991 period. Theoretically, these parameters could be reduced, but population estimates relative to the baseline period would likely be seriously compromised.

Unlike the modified Schaefer method for chinook salmon, which is accomplished independently for any given spawning season, the striped bass mark-recapture program relies on recaptures over a period of up to 5 years. The recapture sampling program cannot be deleted in any given year without affecting the precision and accuracy of population estimates. For this reason, funding for adult striped bass monitoring needs to be considered on a long-term basis and in the context of other funding needs. Unfortunately, funding will likely continue to be on a year-by-year basis, rather than long-term. Consequently, the striped bass mark-recapture program may need to be opportunistic by employing the recommended program when funds are available. This practice is not desirable on a scientific or long-term monitoring basis, but may need to be employed if current funding priorities and processes continue in the future.

If a low-effort program is mandated by fiscal constraints, stratified sampling over many years would be preferable to compromising the existing sampling protocol by reducing sampling sites or other similar measures. The most effective low-effort program would be to continue the annual recovery effort each year. This sampling design would optimize the number of tagged fish that are recaptured, even though tagging would occur on a less-frequent basis.

A more extreme low-effort program is to institute the striped bass sampling program in 5- to 10-year blocks (5-10 years of annual sampling followed by 5-10 years without any sampling). The nature of the striped bass mark-recapture program does not allow for intermittent sampling over time (for example, once every 5 years), and this type of low-effort program would maintain the continuity of the sampling, but over only certain blocks of time. This sampling strategy could serve the long-term needs of CAMP after approximately four repetitions of the sampling blocks are completed. Such sampling in 8-year blocks in 1996-2003, 2012-2019, 2028-2035 and 2044-2051 would, over the course of approximately 50 years, provide reasonable estimates as to whether striped bass populations are being doubled on a long-term basis and would provide interim milestones of progress for meeting doubling goals. Staffing this type of discontinuous sampling program would be extremely difficult, program continuity would be compromised, and striped bass population estimates would be much less precise and accurate as compared to other available alternatives.

The potential precision and accuracy of each of these low-effort programs could be tested by incorporating or deleting data from the 1967-1991 baseline period to match the designs described above and then to compare the resulting population estimates from low-effort programs to those obtained using the existing monitoring efforts.

## American Shad

### Recommended Program

The recommended program to accurately assess achievement of the American shad restoration goal is to:

- continue the fall MWT surveys consistent with the 1967-1991 period and
- calculate the juvenile shad MWT abundance index annually.

This program would thus be continued in the same manner as it was conducted during the 1967-1991 baseline period. The existing program is described in detail in Chapter 3.

**Unmet Needs.** DFG funding for continuing the fall MWT surveys needed to determine the annual juvenile shad abundance index is expected in 1996 because of the need to sample Delta smelt. Continued funding of the fall MWT surveys is critical because no other comparable methods will provide the necessary data to evaluate whether the American shad juvenile abundance index is being doubled on a long-term basis. In addition, no other species is sufficiently similar to American shad to serve as an indicator for evaluating whether CVPIA actions are effectively doubling the American shad juvenile index. Because American shad is a target species for CVPIA, and no other indicator species can be used for American shad, continued sampling for American shad is necessary to meet CAMP goals. Continued funding of the existing fall MWT surveys is considered to be of high priority because there is no other program in place that will collect similar data.

### High-Effort Program

A high-effort program could be employed in several ways, to improve the precision and accuracy of the juvenile shad MWT index. The fall MWT sampling does not include the entire temporal period that juvenile shad are present in the system or the entire geographic area used by juvenile shad in the Delta. The current MWT efforts could be intensified by increasing sampling locations, periods, and effort. The existing sampling program could be continued to provide shad index estimates comparable with the 1967-1991 baseline period, while simultaneously and independently improving the index over time by increasing the sampling effort.

Other high-level programs could be developed to provide systemwide estimates of adult American shad. Employing such high-level programs represents an important decision point, however, as the current use of a juvenile shad index as the AFRP monitoring goal is not preferable but necessitated by a lack of any consistent measure of adult abundance. The only 1967-1991 baseline data that exist for adult American shad were developed as part of the only comprehensive and systematic investigation of American shad population dynamics and life history characteristics conducted to date in California (Painter et al. 1980). The two population estimates, for 1976 and 1977, were derived from mark-recapture studies. Adult fish were captured in gill nets in the Delta near Pittsburg during their upstream migration in March, April, and May and recaptured via angler

surveys of areas upstream from the tagging and release site in the upper Sacramento, Feather, Yuba, and American rivers. Unlike the adult striped bass monitoring program, a high-level program to estimate adult shad abundance can be conducted in any given year. Consequently, the program that was used to arrive at the two previous population estimates for American shad could be duplicated in any given year. Duplicating the previous efforts on a consistent temporal basis, such as every 5 or 10 years, would provide an excellent basis to examine American shad population trends. Integrating such data collected every 5 or 10 years with the annual juvenile shad MWT index would, after about 25 years, provide a much-improved estimator of the effects of CVPIA actions on American shad populations.

Over time, other adult shad estimates could be developed with, or in place of, the extensive program described above. Consistent angler surveys conducted on the major shad spawning rivers could be used in the absence of a tagging program to develop catch per unit effort indices of adult American shad. Data from such a program could be compared to the few years of data available from employing similar methods in the 1967-1991 baseline period, as well as to track long-term trends in the future. Fyke net sampling in the Sacramento River could also be used as an index of adult shad abundance if a sampling location is monitored downstream of the American River on a consistent temporal basis. Both of these indices would be biased by flow-related factors.

### **Low-Effort Program**

Any low-effort program should not compromise the sampling gear, locations, and protocol that were instituted during the 1967-1991 period. Theoretically, these parameters could be reduced, but the juvenile shad MWT abundance indices relative to the baseline period would likely be seriously compromised.

The MWT sampling program could be conducted less frequently than the annual basis that has been employed during the 1967-1991 baseline period. Collecting these data every other year would provide a measure of long-term changes in the abundance index over a 25-year or longer period. Monitoring once every 5 years over a 25-year period, however, would not provide a sufficient sample size to reasonably draw conclusions regarding attainment of doubling on a long-term basis. American shad differ from striped bass in that shad populations consist of fewer year classes, and spawning run sizes are more variable. These factors make it just as difficult to implement a low-effort program for American shad as it is for striped bass.

## White Sturgeon and Green Sturgeon

### Recommended Program

The recommended program for accurately assessing achievement of the white sturgeon and green sturgeon restoration goals is to:

- continue the existing mark-recapture program for adult white sturgeon;
- estimate abundance, catch, and natural production estimates for age 15 white sturgeon as currently calculated; and
- estimate the adult population of green sturgeon as currently calculated.

These programs would thus be continued in the same manner as they were conducted during the 1967-1991 baseline period. Tagging efforts should be conducted on a consistent basis, preferably for two consecutive years every 2-5 years so that enough fish are tagged that they show up in meaningful numbers as recaptures. The existing program is described in detail in Chapter 3.

**Unmet Needs.** DFG funding for continuing the mark-recapture sampling that is necessary to achieve sturgeon population estimates has been eliminated after June 30, 1996. Without the continued funding of the sampling programs for sturgeon, there will be no comparable methods that will provide the necessary data to evaluate whether sturgeon populations are being doubled on a long-term basis. In addition, no other species is sufficiently similar to white sturgeon and green sturgeon to serve as an indicator for evaluating whether CVPIA actions are effectively doubling sturgeon populations. Any sampling program for the more common white sturgeon also lends itself to sampling green sturgeon, but increased sampling would be necessary for green sturgeon to develop a population estimate with the same precision and accuracy as the current white sturgeon estimates. Because white sturgeon and green sturgeon are target species for CVPIA, and no other indicator species can be used in their place, continued sampling for white sturgeon and green sturgeon is necessary to meet CAMP goals. Continued funding of the existing sturgeon mark-recapture program is of high priority because there is no other program in place that will collect similar data.

### High-Effort Program

A high-effort program could serve to improve the precision and accuracy of sturgeon population estimates. The current mark-recapture program could be intensified by increasing sampling locations, periods, and effort. Tagging efforts could be conducted on an annual basis, or some other consistent basis, rather than the intermittent basis by which sampling is currently conducted. Tagging and recovery efforts could be increased to provide greater sample sizes and, therefore, more precise population estimates. Additional locations could be sampled, but this sampling is less desirable than increasing existing efforts at previously sampled locations. Increased sampling would likely lead to more green sturgeon tagged and recaptured, especially if different time

periods were sampled. Under the current sampling program, sample sizes are insufficient to develop independent population estimates for green sturgeon. Under an expanded program, more green sturgeon would be tagged and possibly recaptured, potentially providing sufficient sample sizes to develop independent green sturgeon population estimates.

### **Low-Effort Program**

Any low-effort program should not compromise the sampling gear, locations, and protocol that were instituted during the 1967-1991 period. Theoretically, these parameters could be reduced, but population estimates relative to the baseline period would likely be seriously compromised.

The current sturgeon sampling program essentially represents the low-effort program. The number of recaptures for both species has been declining and is at the point where the population estimates, even for white sturgeon, border on being an index rather than a scientifically valid population estimate. Increased populations may help the sample size dilemma, but further reductions in the sturgeon program will exacerbate the ongoing sample size problems and likely result in increasingly unreliable estimates of adult sturgeon production. Sturgeon population estimators are similar to those for striped bass whereby several years of sampling are required to provide reliable population estimates. The greater longevity of sturgeon would suggest that longer intervals between tagging and recapture could occur, but the number of recaptured sturgeon is currently so low that reducing the tagging and recapture efforts will result in even fewer returns.

If a low-effort program is mandated by fiscal constraints, it would be better to stratify sampling over many years than to compromise the existing sampling protocol by reducing sampling sites or other similar measures. Unlike for striped bass, the major need for sturgeon population estimates is to tag sufficient numbers of fish. Currently, the number of tagged fish is near the minimum necessary to achieve reasonably accurate population estimates. Tagging every third, fourth, or fifth year would yield increasingly lower numbers of recaptures. If populations increase, however, this type of low-effort program would maintain the continuity of the sampling and could serve the long-term needs of CAMP after approximately 100 years, given the longevity of sturgeon.

Continuing the annual recovery effort each year without sufficient tagging is not as desirable for sturgeon as it is for striped bass because without sufficient tagging of sturgeon there would likely be very few returns. The potential accuracy of any low-effort program could not be reasonably tested for sturgeon because of the small number of years (8) with sturgeon production estimates and the great longevity of individual sturgeon.

Staffing of the sturgeon programs should be done in an integrated fashion with the striped bass program, as is currently being done. In this way, any reduced sampling design can be coordinated more efficiently in terms of the specific years when sturgeon and striped bass tagging and recovery programs will be employed.

## **PROGRAM FOR ASSESSING EFFECTIVENESS OF ACTION CATEGORIES IN DOUBLING POPULATIONS (GOAL #2)**

### **General Overview**

This section builds primarily on Chapter 4, which defines the actions and action categories, limiting factors, target species and races, life stages, and general monitoring needs and designs. Based on Chapter 4 results, fall-run, winter-run, and spring-run chinook salmon, and striped bass, were selected as target species. This section provides general considerations and guidelines for developing an Implementation Plan for assessing action category effectiveness for these species. Additional detail, such as was presented for meeting Goal #1, cannot be developed until further information is available regarding specific AFRP actions.

The duration of the monitoring programs required for determining long-term population trends has been established for Goal #1 as 25-50 years for chinook salmon and striped bass. Most action- and site-specific AFRP actions, however, will be monitored over a much shorter time frame (2-5 years). The effectiveness of many actions can be measured within this time frame in relatively simple terms. Such measures may include the presence of adults on newly restored spawning gravels, fish successfully ascending a fishway, juvenile fish using habitats restored by adding woody debris, or fish being successfully screened. The need to conduct additional monitoring of a fish screen that is proven to increase juvenile survival, for example, or a fish ladder that allows successful passage of chinook salmon, is not warranted.

Evaluating the effectiveness of a given action category relative to another can best be accomplished by expressing the benefits of those actions in terms of their relative contribution to total juvenile or adult production. Because of high natural variability in anadromous fish populations and the length of time typically needed to observe a population response, such evaluations will generally require an extended monitoring period that encompasses a few to several generations to adequately assess the population response to various restoration action categories. Possibly the greatest role for CAMP will be to ensure that short-term, action-specific monitoring programs have the most effective temporal and spatial controls possible, and that data are collected, stored, and available to CAMP in a consistent manner. Continuing adult population estimates for a 25- to 50-year period, and developing juvenile population estimates for approximately a 10-year period in several key watersheds will provide the basis for integrating the short-term monitoring results and evaluating the effectiveness of action categories in key watersheds.

It needs to be reiterated that CAMP will not influence the priority or scheduling of any restoration actions. In other words, CAMP will not impede the implementation of restoration actions in any way. The monitoring considerations and guidelines are presented only to present a conceptual-level process of how CAMP will be implemented to take advantage of any opportune sampling conditions.

## Chinook Salmon

### Watershed Selection

As stated in Chapter 4, there are no watersheds in which a single category of actions is intended for implementation. In all watersheds, more than one action category is recommended for implementation, which means that the effects of action categories cannot be isolated in any watershed based on current recommendations. Phased AFRP restoration, however, will undoubtedly allow some isolation of actions in individual watersheds, but only on a short-term basis. The AFRP Restoration Plan may also eliminate or revise some of the specific actions included in its Working Paper, thereby potentially allowing isolation of actions in individual watersheds. Additionally, ongoing prioritization of CVPIA actions by the Service could also result in temporal isolation of categories of actions in watersheds. That is, in some watersheds, only one category of actions might be considered implementable for a specified time based on prioritization of CVPIA actions. If the time period is sufficient to encompass several generations of anadromous fish, monitoring in these watersheds may be useful to evaluate the relative effectiveness of the four categories of actions. Again, CAMP will need to evaluate on an annual basis, particularly in the first few years of implementation, any opportunities to isolate actions, species, and/or watersheds for meeting CAMP Goal #2.

The final and prioritized AFRP Restoration Plan will be helpful in selecting actual monitoring locations for CAMP to assess the effectiveness of action categories. The CAMP Project Team can proceed at this time only with a preliminary selection of specific target watersheds based on the AFRP Working Paper. These preliminary watersheds, specified in Chapter 5, would need to be reevaluated and modified in the near future to incorporate appropriate information included in the AFRP Restoration Plan. In concert with the AFRP Restoration Plan, greater specificity on the locations of provision-specific monitoring is essential to CAMP. For example, numerous diversions are expected to be screened by implementing Section 3406(b)(21). The CAMP Project Team, however, does not know which diversions will be screened and which of the screened diversions will be subject to site-specific monitoring. It is assumed that even within the monitoring required for provision-specific actions under the AFRP, some subsampling of the specific actions associated with many of the provisions will be required.

In addition to determining the specific watersheds to be affected by the various categories of actions (test watersheds), it would be desirable to select a watershed or watersheds where no categories of actions will be implemented (control watershed). Changes in natural production of fall-run chinook salmon in the control watershed could indicate variability in production that is not largely associated with any category of actions. The use of control watersheds would be most applicable to fall-run chinook salmon, by virtue of its broad distribution and relative isolation in watersheds. As is the case with test watersheds, it is premature to select a specific control watershed at this time. Attributes of a control watershed include accurate 1967-1991 baseline population estimates for fall-run chinook salmon; minimal or no CVP operations and CVPIA actions; and no other actions that would change watershed characteristics, flow regimes, temperature patterns, and overall habitat conditions in the future.

## **Reliance on Other Monitoring Programs/Databases**

CAMP does not include major funding to initiate extensive and expensive monitoring efforts but must rely primarily on making the best use of existing monitoring programs and those programs that will be established as part of the implementation of each 3406(b) provision. Although substantial information could be obtained through large-scale research and monitoring, CAMP is not currently funded to provide such research and monitoring. Such activities, however, could be accomplished through CVPIA Section 3406(b)(1). The process of developing CAMP must realistically assess the probability of implementing such monitoring. As future monitoring unfolds for 3406(b) provisions and other actions, CAMP will need to be flexible enough to incorporate any such monitoring into its overall design. These other monitoring programs, particularly those for each 3406(b) provision, represent the cornerstone for CAMP, yet have not been adequately defined to provide meaningful input into CAMP. In addition, budget and funding requirements of CAMP in relation to other monitoring programs are not addressed in this Conceptual Plan but will be explored in CAMP's Implementation Plan.

## **Constraints**

The lack of clear distinction between the effects of the categories of actions makes discriminating between the relative effectiveness of the categories extremely difficult and much less than a precise science. The desire to immediately implement as many of the provisions as possible to quickly restore fish populations, and the reality that implementation of provisions in various watersheds will be opportunistic and subject to funding availability, prevents or impairs development of a scientific design and implementation schedule that would best facilitate evaluating the effectiveness of each action category. Ideally, distinguishing the effectiveness of the categories of actions would best be accomplished by implementing only one category of actions on a subset of similar and highly controlled tributaries in the Central Valley system. For example, water management modifications in the form of restored flows would be the only action category implemented on one to several tributaries. Similarly, screened diversions, habitat restoration, and structural modifications would each occur in isolation on one to several other watersheds in the Central Valley. Assuming no other differences among these tributaries, which is a very tenuous assumption at best, differences in some measure of fish production on these tributaries could be attributed to differences in the effectiveness of the category of action implemented on that stream relative to baseline (1967-1991) conditions. It is clear that the real conditions facing CAMP fall far short of providing such an optimal experimental design that cleanly apportions variation in fish production among several controlled variables.

Several key biological and physical factors can constrain the ability to evaluate the relative effectiveness of categories of actions under 3406(b). Each of these factors can independently limit the ability to determine the relative effectiveness of each action category in achieving anadromous fish doubling goals. These factors include:

- exposure of fish to many uncontrolled, unquantified, and unknown variables during life stages that occur beyond the range of influence of CVPIA actions (e.g., oceanographic effects, effects in non-CVP streams, and upstream watershed effects);
- multiyear age classes for spawning anadromous fish;
- mixed populations of hatchery, naturally produced, main river, and tributary river spawners; and
- hydrologic variation geographically, daily, monthly, seasonally, and annually.

Several planning-related factors also present constraints to developing specific monitoring designs for evaluating the effectiveness of the action categories. The following factors, which CAMP is very much dependent on, provide additional constraints for CAMP:

- uncertainty about specific timing, location, and actual action to be taken in some provisions of 3406(b) other than (b)(1);
- uncertainty about which AFRP [(b)(1)] actions recommended in the Working Paper will be retained in the AFRP Restoration Plan;
- proposed implementation of more than one category of actions in all tributaries and rivers; and
- the effects of currently undetermined actions included under other subsections of CVPIA, such as 3406(c), and recommendations provided by supporting investigations identified in subsection 3406(e)(3) and (e)(6).

## **Water Management Modifications**

**General Monitoring Considerations.** The CVPIA 3406(b) provisions and AFRP restoration actions include numerous water management modifications that are generally directed at improving habitat conditions for chinook salmon in streams or reaches where existing flows and associated habitat parameters are believed to limit salmon production. Specific objectives of these actions include:

- providing adequate passage of adult salmon to important spawning areas;
- providing pulsed flows to attract adult salmon upstream;
- increasing the quantity and quality of physical habitat available for spawning and rearing;

- augmenting spring flows during principal juvenile emigration periods and managing reservoir storage and release schedules to control downstream water temperatures during critical seasons; and
- reducing diversions along principal juvenile migration routes.

Water management modifications often affect salmonid populations at the basin or subbasin level and result in overall population responses that are best evaluated by determining changes in smolt numbers (or juvenile outmigrants) before and after implementing water management modifications. Changes in the number of fish reaching the smolt or outmigrant stage will best reflect whether a given action was successful in reducing or eliminating the effect or factors that were limiting at earlier stages. An alternative method for assessing total juvenile population is using the cost-effective sampling design suggested by Hankin and Reeves (1988) for estimating total fish abundance in small streams based on visual estimation by snorkeling surveys. To be meaningful, this estimate should be made late enough in the rearing season to represent as closely as possible the number of smolts or juvenile outmigrants ultimately produced.

Clear Creek is a good candidate for evaluating water management modifications because increased flow during critical periods is proposed as the primary action for providing suitable spawning, incubation, rearing, and outmigration conditions for salmon and steelhead production. Additionally, Clear Creek's relatively small size and the ability to regulate streamflows are important for successful monitoring of adult and juvenile salmon populations. For example, a fish counting weir could be established on Clear Creek to intercept chinook salmon adults and juveniles migrating to and from a selected portion of the stream. Adult production should continue to be monitored to determine the degree to which changes in adult production can be tied to changes in juvenile production. Because of high natural variability in juvenile and adult production from year to year, it will be important to evaluate juvenile production for at least two life cycles (8 to 10 years) and adult production for at least five life cycles (20 to 25 years) to ensure sufficient time to detect a response.

Because of the high annual variability in smolt production and known difficulties in reliably estimating smolt abundance (especially in large rivers), alternative means of measuring population responses to water management modifications will be required. For example, increasing flow releases to facilitate downstream migration of juveniles and moderate water temperatures will potentially have survival benefits that can be measured by conducting mark-recapture experiments using "treatment" and "control" groups of marked juveniles to estimate survival under variable flow conditions. The Service's existing program to estimate survival of hatchery smolts through the Delta should be continued and expanded to include selected tributary streams where water management modifications are proposed. For example, outmigrant trapping programs currently in place on the American and Merced rivers could be adapted to assess the effectiveness of pulse flows by comparing the relative recovery rates of marked hatchery salmon released upstream and downstream of selected evaluation reaches. In streams where hatchery stocks are not present or have minimal influence (e.g., Yuba River), such evaluations should be conducted using juveniles produced from native brood stock.

Monitoring the effectiveness of flow modifications to improve adult passage may simply involve comparing spawner distribution among years with differing migration flows. Deer Creek

offers one of the best locations for evaluating this action because inadequate flow for upstream migration of adult salmon and steelhead is recognized as a key limiting factor, especially in dry years. Additionally, Deer Creek is one of the few streams for which a valid control stream exists (Mill Creek). Continuation of upstream and downstream migrant trapping at Stanford-Vina Dam would provide valuable information on the success of upstream migration at different flows as well as serve to estimate resulting increases in juvenile production from upstream spawning areas. This is important because juvenile production generally provides a standard measure with which the effectiveness of the different action categories can be compared.

Flow and temperature data, in conjunction with estimates of juvenile and adult abundance, will provide the basis for evaluating the effect of a given water management action on juvenile and adult populations. Consequently, a prerequisite in selecting streams or reaches for evaluating water management modifications is that adequate baseline flow and temperature records exist and will continue to be maintained in the future. Accurate assessment of the effect of water management actions on water temperatures would be further enhanced by developing or applying existing water temperature models to estimate changes in water temperatures under existing and prescribed flow conditions.

**General Monitoring Guidelines.** The following list summarizes general guidelines for evaluating the effectiveness of water management actions in meeting CAMP Goal #2 relative to the monitoring needs for chinook salmon:

- Select streams or reaches where changes in water management will be the primary restoration action.
- Select streams or reaches where baseline estimates of spawner abundance can be used to evaluate future trends in adult abundance.
- Select streams or reaches where daily flow and water temperature data exist and will continue to be measured in the future.
- Select streams or reaches where overall juvenile production can be reasonably estimated and where downstream migrant trapping programs already exist or are being planned.
- If adequate baseline data on juvenile production are not available, conduct outmigrant trapping until water management actions are implemented.
- Where estimating juvenile production is impractical, conduct mark-recapture experiments using "treatment" and "control" groups of marked juveniles to estimate survival of downstream migrants under variable flow conditions.
- Monitor juvenile production for at least two life cycles (10 years) and adult production for at least five life cycles (25 years) on test watersheds.

## Structural Modifications

**General Monitoring Considerations.** Structural modifications include physical modification of dams, water diversion intakes, and conveyance facilities to minimize or prevent direct and indirect losses of anadromous fish associated with the operation of these facilities. In contrast with water management actions, structural modifications tend to be site-specific in their effect on fish populations because they often involve measures to improve fish passage at specific structures along the migratory route. Such actions include:

- constructing or upgrading fish ladders at diversion facilities to improve passage of upstream migrating adults,
- installing new control structures or fish barriers to prevent juveniles from being diverted off desired migration routes, and
- installing or upgrading existing fish screens and bypass systems to reduce or eliminate entrainment losses and predation of juveniles at diversion facilities throughout the Central Valley.

The benefits of structural modifications are generally measured in terms of the proportion of fish that are safely bypassed through or around these structures without significant delays. The simplest means of evaluating the effectiveness of a fish ladder would be to monitor the proportion of a salmon run spawning above and below a ladder before and after its installation or modification. Evaluating the performance of a fish barrier or fish screen can best be accomplished by comparing the recovery rates of "treatment" and "control" groups of marked salmon released above and below a diversion facility. Alternatively, survival or fish bypass efficiency could be determined if total numbers of juvenile salmon approaching and bypassing a diversion structure could be accurately estimated by trapping.

A meaningful comparison of the value of these actions relative to other actions (e.g., water management modification) will require translating the measured benefits (e.g., increases in survival or proportion of fish bypassed) into a measure of the contribution of that action to total juvenile production or some other standard production unit. As discussed earlier, small streams offer the best opportunity for accomplishing this because they are relatively isolated from confounding effects outside the basin, are subject to watershed effects that are more readily detected, and provide stream conditions which make sampling and monitoring of the entire fish population possible. A good example of such an opportunity exists on Butte Creek.

Key restoration measures on Butte Creek include the removal of several dams and installation of new ladders on several other existing dams to provide passage for adult spring- and fall-run chinook salmon. Providing adequate instream flows for all life stages of salmonids is also a high priority restoration action. Because most streams for which structural modifications have been proposed also have some form of flow augmentation, evaluating the independent effects of these two actions would best be accomplished if these actions were implemented sequentially on the same stream and the population response monitored over separate time periods. On Butte Creek, this could be

accomplished if all of the structural modifications were implemented first and the water management actions second. DFG is currently conducting downstream migrant trapping on Butte Creek which may provide adequate baseline data on juvenile spring-run chinook salmon production prior to implementing the restoration actions. It would be desirable to have pre- and post-restoration monitoring for at least two life cycles (10 years), but this is unrealistic and CAMP will need to adapt to whatever restoration schedule is ultimately implemented.

**General Monitoring Guidelines.** The following list summarizes general guidelines for evaluating the effectiveness of structural modifications in meeting CAMP Goal #2 relative to the monitoring needs for chinook salmon:

- Select streams or reaches where structural modification is a primary or key restoration action.
- Select streams or reaches where baseline estimates of spawner abundance can be used to evaluate future trends in adult abundance.
- Select streams or reaches where overall juvenile production can be accurately estimated and where downstream migrant trapping programs already exist or are being planned.
- Select streams where sequential monitoring of the effects of structural modifications and other actions may be possible.
- If adequate baseline data on juvenile production are not available, conduct outmigrant trapping until structural actions are implemented.
- Where estimating juvenile production is impractical, conduct mark-recapture experiments using "treatment" and "control" groups of marked juveniles to estimate survival or fish bypass efficiency.
- Monitor juvenile production for at least two life cycles (10 years) and adult production for at least five life cycles (25 years) on target watersheds.

## **Habitat Restoration**

**General Monitoring Considerations.** Habitat restoration actions include activities that attempt to restore physical habitat by replacing, repairing, or replenishing those physical attributes of a stream that are considered to be limiting fish production. Examples of these activities include:

- adding gravels to the stream to increase spawning habitat,
- mechanically ripping streambeds to remove fine sediment,
- adding instream cover to increase juvenile rearing habitat, and

- revegetating streambanks to provide cover and food for juvenile salmonids and shade for temperature control.

A common way in which habitat restoration projects have been evaluated is by comparing fish abundance in a treatment area to pre- and post-treatment abundance in a nearby control area. However, Reeves et al. (1991) warn that this type of evaluation can be misleading because the results may reflect only a redistribution of spawners or juveniles rather than a basinwide increase in numbers or production.

To avoid problems associated with using adult and juvenile abundance as measures of the effectiveness of habitat restoration program, Reeves et al. (1991) recommended monitoring changes in basin smolt production as the best alternative for measuring the effect of a habitat restoration action. Additionally, they recommend using treatment and control basins that are close to each other geographically and share similar physical and biological features (e.g., similar species composition) to accurately measure the population response. Because suitable control basins are not likely to be found among the streams proposed for restoration through the AFRP, emphasis should be placed on comparing total juvenile production (in terms of annual juvenile outmigrant numbers or late-season juvenile rearing abundance) before and after treatment.

Again, it would be desirable to limit the size of the basin for which juvenile production estimates are made to smaller streams or reaches where estimates of juvenile production can be reasonably measured. For example, changes in overall juvenile production resulting from restoration of spawning gravel in Clear Creek could be effectively monitored by installing a counting weir downstream of McCormick-Saeltzer Dam. A trapping facility could be constructed at the McCormick-Saeltzer Dam if a solution can be found to existing adult passage problems. Cottonwood Creek is also a good candidate for evaluation of habitat restoration actions because protecting and enhancing spawning gravel was identified as a key action in restoring chinook salmon and steelhead production.

**General Monitoring Guidelines.** The following list summarizes general guidelines for evaluating the effectiveness of habitat restoration actions in meeting CAMP Goal #2 relative to the monitoring needs for chinook salmon:

- Select streams or reaches where baseline estimates of spawner abundance can be used to evaluate future trends in adult abundance.
- Select streams or reaches where overall juvenile production can be accurately estimated and where downstream migrant trapping programs already exist or are being planned.
- Select streams where sequential monitoring of the effects of habitat restoration and other actions may be possible.

- If adequate baseline data on juvenile salmon production are not available, conduct annual outmigrant trapping or estimate annual rearing abundance until habitat restoration actions are implemented.
- Monitor juvenile production for at least two life cycles (10 years) per restoration action category and adult production for at least five life cycles (25 years) in target watersheds.

## **Fish Screens**

**General Monitoring Considerations.** The general considerations described for structural modifications also apply to fish screens. A separate evaluation of fish screens can be conducted by selecting appropriate evaluation sites or reaches. Most of the existing baseline data on juvenile salmon survival and bypass efficiency at screens are available for major water diversions on the Sacramento River and other large Central Valley rivers. However, the ability to translate these measured benefits into an overall population response comparable to the responses measured for other restoration actions is limited. As discussed above, the preferred approach would be to conduct such evaluations on small tributary streams or reaches where the overall population response to a given action can be reasonably monitored. Because more than one restoration action category is generally being proposed for the target streams, a sequential evaluation approach is also recommended whenever possible. Candidate streams for evaluating the effectiveness of fish screens include Battle Creek, Butte Creek, and Cow Creek.

**General Monitoring Guidelines.** The following list summarizes general guidelines for evaluating the effectiveness of fish screens in meeting CAMP Goal #2 relative to the monitoring needs for chinook salmon:

- Select streams or reaches where fish screens are a primary or key restoration action.
- Select streams or reaches where baseline estimates of spawner abundance can be used to evaluate future trends in adult abundance.
- Select streams or reaches where overall juvenile production can be accurately estimated and where downstream migrant trapping programs already exist or are being planned.
- Select streams where sequential monitoring of the effects of fish screens and other actions may be possible.
- If adequate baseline data on juvenile production are not available, conduct outmigrant trapping until the fish screen program is implemented.
- Where estimating juvenile production is impractical, conduct mark-recapture experiments using "treatment" and "control" groups of marked juveniles to estimate survival or fish bypass efficiency both before and after fish screening.

- Monitor juvenile production for at least two life cycles (10 years) and adult production for at least five life cycles (25 years).

## **Striped Bass**

### **Watershed Selection**

For CAMP, striped bass are considered one population that is concentrated in the Bay and Delta. Although striped bass are distributed far up the rivers and tributaries, and can reside at various times of the year from coastal waters to major tributaries, Delta conditions play a major role in striped bass ecology and population dynamics. Consequently, only the effects of the four action categories as they affect Delta conditions will be considered for striped bass.

### **Reliance on Other Monitoring Programs/Databases**

IEP and DFG's Bay/Delta Division have monitored striped bass populations and habitat conditions in the Delta extensively. Much of the information collected and stored on IEP databases will be directly applicable toward meeting CAMP Goal #2 for striped bass. CAMP will rely almost exclusively on continued monitoring by IEP and DFG, and AFRP's short-term and action-specific monitoring, to provide data for CAMP needs associated with striped bass and Delta conditions.

### **Constraints**

General constraints on evaluating the effects of action categories on striped bass are the same as those discussed in the previous section on chinook salmon; these general constraints are not reiterated here. Several factors specific to striped bass limit the potential effectiveness of meeting Goal #2 for striped bass. First, each action category will likely be implemented within the Delta, thus making it difficult to separate the effectiveness of individual categories. Second, changes in other species will also affect striped bass, since striped bass are a major predator at the top of the food web. Third, some of the analyses required to assess the effectiveness of action categories will require rigorous analyses of existing and future databases to separate and determine effects from the four action categories, as well as control for other non-CVPIA actions that will be simultaneously implemented in the Delta for striped bass as well as for other species. Finally, data needed for Goal #2 may not be available in the future due to cutbacks in the IEP and DFG funding, for striped bass, which may receive less priority and funding than other species.

### **Water Management Modifications**

**General Monitoring Considerations.** Flow pattern changes (pulses and base flows) in the rivers, Delta, and Bay will potentially affect striped bass in various ways. Spawning patterns (time

and space) would likely change with any water temperature and velocity changes. Larval transport and distribution patterns will change. Juvenile habitat conditions (e.g. salinity, food supply, water temperature, etc) would also likely change. The effect of flow changes on striped bass population dynamics can be viewed in the timing and distribution of juveniles in the lower rivers, Delta, and Bay. Surveys that provide timing and distribution data include the summer tow net survey and various trawl surveys. Data analysis would entail comparing striped bass distribution and abundance before and after the full array of water management modifications are implemented under Section 3406(b) actions. Effects can also be viewed in long-term patterns in juvenile and adult abundance estimates. Analyzing trends in historical data between striped bass populations and Delta hydrologic, habitat, and structural parameters, and then using this baseline information to compare how striped bass populations respond to the full suite of water management modifications under CVPIA in the future will facilitate the development of general conclusions regarding the effectiveness of water management modifications.

It is likely that many of the effects of Section 3406(b) water management modifications will be masked or impossible to distinguish from the other complex web of factors affecting striped bass production. It is just as likely, however, that specific water conditions may occur at times that can allow effective comparisons of similar conditions with and without the Section 3406(b) water management actions. Sometimes these conditions may not even be fully recognized until after they have occurred. Consequently, consistency in monitoring striped bass populations and Delta conditions is critical to ensure that a thorough database is compiled that will allow meaningful data analyses for identifying contributions of the water management modification category to striped bass population trends.

**General Monitoring Guidelines.** The following list summarized general guidelines for evaluating the effectiveness of water management actions in meeting CAMP Goal #2 relative to the monitoring needs of striped bass:

- Continue summer tow net and fall MWT surveys consistent with 1967-1991 baseline period.
- Collect and conduct rigorous analyses of striped bass young-of-year, juvenile, and adult distribution and abundance data with respect to flow patterns.
- Continue long-term juvenile and adult abundance indices and the monitoring that provides necessary data for those indices.
- Continue daily monitoring of Delta hydrodynamic conditions and overall hydrologic regimes of rivers flowing into the Delta.
- Monitor juvenile production for at least two life cycles (10 years) and adult production for at least five life cycles (25 years).

## **Structural Modifications**

**General Monitoring Considerations.** Structural modifications in the Delta are potentially of many different configurations. Striped bass response to barrier installation in Delta channels can be viewed through comparisons of pre- and post-barrier distributions of striped bass in the area of the barrier. Non-CVPIA structural changes, including water transfer facilities that may greatly alter water flow patterns through the Delta, should also be evaluated by comparing striped bass distributions before and after structural modifications. Generally, structural modifications should be evaluated by monitoring localized distribution patterns of striped bass relative to the structure put in place. In some cases where structures affect broad areas (e.g. cross Delta transfer facility), the effects should be viewed by monitoring over the entire area. In such cases comparison of the pre- and post-structure periods would be prescribed. Long-term trends in juvenile production and adult population indices may also provide some insight into the effects of the changes.

**General Monitoring Guidelines.** The following list summarizes general guidelines for evaluating the effectiveness of structural modifications in meeting CAMP Goal #2 relative to the monitoring needs for striped bass:

- Conduct site-specific monitoring in areas of the structures both pre- and post-treatment.
- Continue summer tow net and fall MWT surveys.
- Conduct rigorous analyses of striped bass distribution data with respect to structures.
- Continue long-term juvenile and adult abundance indices and the monitoring that provides necessary data for those indices.
- Monitor juvenile production for at least two life cycles (10 years) and adult production for at least five life cycles (25 years).

## **Habitat Restoration**

**General Monitoring Considerations.** Habitat restoration actions may take many different forms. Specific monitoring of habitat conditions, particularly those habitat factors that relate to striped bass, would provide an indirect measure of the potential effectiveness of the modifications. However, effectiveness generally will be ultimately measured in terms of striped bass abundance indices. Habitat restoration effects on striped bass should be measured by comparing pre- and post-restoration use of the habitat by striped bass. Monitoring should also quantify specific changes in the physical, chemical, and biological characteristics of the habitat as appropriate. Striped bass abundance indices should also be reviewed to ascertain whether any changes in abundance are in any way related to the habitat changes.

**General Monitoring Guidelines.** The following list summarizes general guidelines for evaluating the effectiveness of habitat restoration actions in meeting CAMP Goal #2 relative to the monitoring needs of striped bass.

- Measure changes in key habitat parameters modified in the Delta that could substantially affect striped bass production.
- Conduct site-specific monitoring in areas of potential habitat restoration before and after changes to determine habitat use by striped bass.
- Continue long-term juvenile and adult abundance indices and the monitoring that provides necessary data for those indices.
- Monitor juvenile production for at least two life cycles (10 years) and adult production for at least five life cycles (25 years).

## Screens

**General Monitoring Considerations.** Screening individual and multiple diversions in the Delta will reduce the number of juvenile striped bass lost to the diversions. The effectiveness of individual screens should be determined as part of the Anadromous Fish Screening Program (b)(21) requirements by comparing pre- and post-screen rates of entrainment. The effectiveness of multiple screening projects can be evaluated through combining the benefits measured for individual screens and by viewing responses in juvenile and adult abundance patterns. Screen monitoring should be conducted at each diversion where screen installation is planned. Monitoring can be a comparison of pre- and post-entrainment. The overall effectiveness of screening in specific regions of the Delta could be evaluated by comparing the relative abundance of striped bass in the regions before and after screening programs are initiated.

**General Monitoring Guidelines.** The following list summarizes general guidelines for evaluating the effectiveness of fish screens in meeting CAMP Goal #2 relative to the monitoring needs for striped bass:

- As part of Section 3406 (b)(21) requirements, conduct site-specific monitoring before and after fish screen modifications at each screen facility.
- Compare relative abundance patterns by subregions in the Delta to determine if screening has improved production and survival in specific subregions.
- Continue long-term juvenile and adult abundance indices and the monitoring that provides necessary data for those indices.
- Monitor juvenile production for at least two life cycles (10 years) and adult production for at least five life cycles (25 years).



## **Data Management and Data Access Program**

## **Chapter 6. Data Management and Data Access Program**

### **INTRODUCTION**

For CAMP to be successful, it will be necessary to continuously compile and analyze existing and new data on target watersheds and fish populations of the Central Valley. Such an effort will require access and some input to the format and management of information to be used to address CAMP goals and objectives. Information needed will come from a variety of sources, formats, governmental agencies, and private entities. A successful data management and access program will depend on cooperation and partnerships between the various parties collecting data to develop a system that supports the needs of all users. In particular, short-term monitoring data collected for site-specific 3406(b) actions must be readily available as they become available for use in evaluating CAMP goals.

The Service, charged with evaluating the effectiveness of the AFRP's fish doubling program and determining action category effectiveness, will need to improve data access, accuracy, and management, while changing and improving databases over time. Flexibility will be a key attribute, as will be the ability to have a database that serves more than just the Service's CAMP needs. A database built on data collection efforts from many different stakeholders will need to be accessible to these different stakeholders. The proposed conceptual-level data management and access program for CAMP is recommended not only to most efficiently meet CAMP needs, but to integrate numerous stakeholder databases under the auspices of IEP.

Existing manual processes of data access, management, and analysis will be inefficient given the potentially large volume of data necessary to properly evaluate action category effectiveness and to produce reports under demanding time frames. There will be a need to consolidate data into common formats, to provide access to the data from numerous sites, and to meet demands of multiple users. In today's technical jargon, there will be a need for a sophisticated enterprise-wide, client-server, application development, or more simply put: a data warehouse. The enterprise-wide aspect of the application will be the need to serve multiple agencies and divisions within agencies, as well as outside users such as stakeholders or partners in cooperative restoration efforts. Such a development will have to function with multiple computing platforms, increasing numbers and variety of users, and multiple databases. The development tool will have to be flexible to handle ever-changing demands. The tool will also require a sophisticated, yet simple user interface, most likely a graphical interface such as a Windows-type program. The system must also have longevity, given the long-term nature of the program, and thus will have to accommodate changes in the user interface, databases, hardware, and software of the operating systems of the users. This chapter describes the proposed data management and access program for CAMP in a conceptual manner.

## GOALS AND OBJECTIVES

CAMP has two main goals for its data management and access program:

- to ensure needed monitoring data are efficiently and properly archived and available and
- to provide a database management system that has the tools needed by CAMP staff to download, review, analyze, and present data.

The first goal requires a data repository or data “warehouse”, and the second goal requires a data “mart” that provides the necessary tools (i.e., software capabilities) to readily access available data. Raw data acquisition and storage is an important part of this program but does not replace sound data analysis and interpretation. Simply managing and storing data is useless if those same data are not subsequently accessed, analyzed, and interpreted. The conceptual data management, access, and analysis program presented herein has been developed to maximize data analysis and interpretation.

### Data Warehouse

The Service and other agencies have committed to providing a central data repository within IEP. The IEP comprises federal and state resource agencies conducting numerous studies within San Francisco Bay, the Sacramento-San Joaquin Delta, and other rivers and tributaries in the Central Valley. The IEP studies include many needed by CAMP. The IEP has begun development of the basics of a data warehouse<sup>1</sup> for monitoring data collected by its member agencies. Data from IEP monitoring programs are being archived on a file server at DWR’s Central District office in Sacramento. IEP plans include storing ASCII “flat” files of the original raw survey data as a formal archive of the monitoring study data and providing a relational database management system such as Oracle to facilitate user queries of the stored data. IEP file servers are also located at IEP offices in Stockton. Related databases are maintained by the San Francisco Estuary Institute at Richmond on San Francisco Bay and at USGS facilities in Menlo Park. Plans call for all being linked via the Internet.

The IEP data storage project is supported by water agencies hoping to dramatically reduce the time that staff spend searching for and acquiring information on the Bay-Delta and its watershed. A central repository of information also will help ensure data quality and integrity, and one sanctioned source of information for end users.

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<sup>1</sup> In this context a “data warehouse” is a set of archived data files along with the capability for data queries and downloading in the form of a database management program such as Oracle to serve the needs of the end users.

Lacking from the present IEP data storage plans are data from non-IEP monitoring programs being conducted by its member agencies and other parties, especially those programs in the upper rivers and tributaries of the basin. Many of these programs collect information needed by CAMP; thus, the focus of CAMP database management efforts may be best served by giving CAMP the responsibility to obtain these data for input into the IEP data warehouse.

CAMP plans to support the development of a centralized data warehouse at IEP facilities, under the direction of IEP staff. IEP is presently in the planning phase for its system and is receptive to the specific needs of CAMP and other programs. In developing recommendations for the CAMP data management and access program, the Service has worked closely with IEP staff to understand IEP needs and planning options for the IEP data management and access needs.

### **Data Mart**

To take full advantage of the monitoring data archived in the data warehouse to achieve program objectives, CAMP staff will require other data capabilities to complete its needs related to assessing the effectiveness of the full array of actions planned to restore the anadromous fish populations. These capabilities include an ability to:

- query the IEP data warehouse through the available IEP tools (database management system);
- download query data tables to CAMP staff computers; and
- reformat, analyze, interpret, and present the relevant data.

The set of needed capabilities is termed a data mart. The data mart with its set of software capabilities can reside either on IEP files servers on the IEP computer system or on CAMP staff computers, or both, as long as CAMP users have direct access to the capabilities. The data mart should have the following characteristics and capabilities:

- In many cases, data summarized from the raw study data will be stored in the data mart in a form and context needed by CAMP staff. Data from different sources will need to be integrated and transformed according to a planned data model.
- The data mart should have access to original archived data in the IEP data warehouse in case further information is needed at any time. Access tools should be made available to the end users through multidimensional databases and maps of the data warehouse.
- The data mart should have a standard graphical user interface in the form of a Windows program to allow ease of use.

- Outside user groups, including agency staff, decision makers, and various stakeholders, should be provided access to portions of the data mart via the Internet. (This service could be provided via a CAMP Internet Homepage.)
- The data mart should provide data analysis and presentation tools to support the basic needs of users.

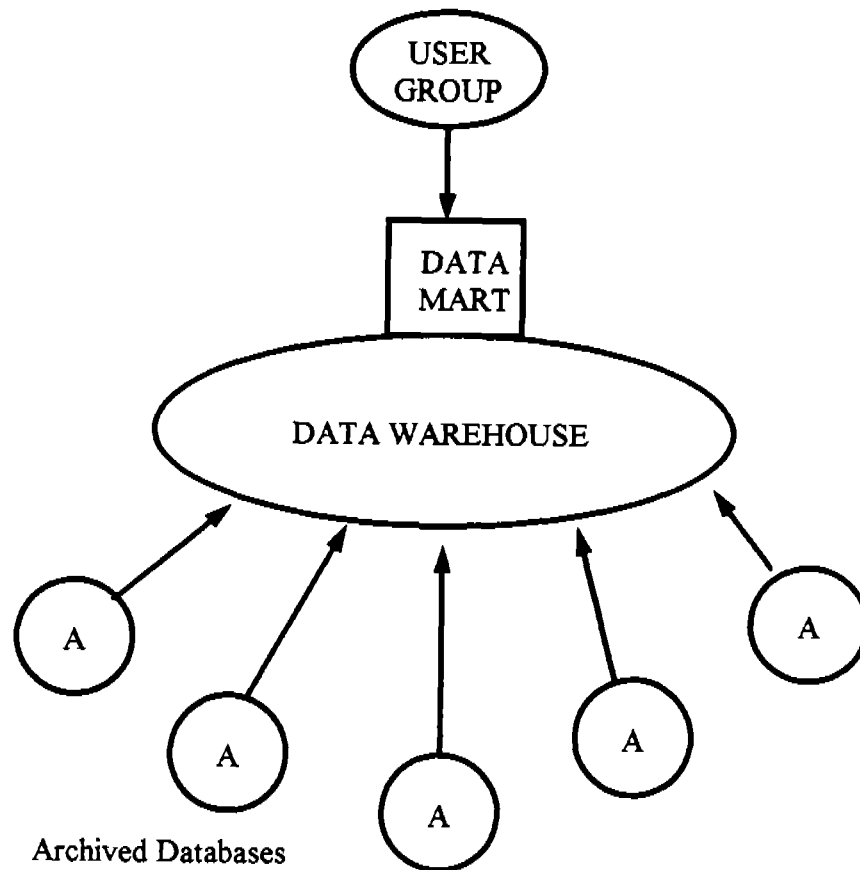
## **PROPOSED CONCEPTUAL-LEVEL DATA MANAGEMENT AND ACCESS PROGRAM**

The proposed conceptual-level data management and access program was designed to meet the goals and objectives described above at a conceptual level. First, the program has the capability to archive original survey/study data in the original formats in a data warehouse. Second, the program has a data warehouse where the original data are integrated into a relational database, managed, reformatted, summarized, and evaluated for quality. Third, the program includes a data mart whereby CAMP users are provided access, downloading, and analyses capabilities for specific data sets or subsets from the data warehouse. A conceptualization of the data management and access program is presented in Figure 6-1.

The high degree of interrelationship between CAMP and IEP cannot be overstated as the conceptual data management and access program is described below. CAMP data management needs to fit within the larger context of IEP's data management needs. Consequently, the conceptual data management and access program presented below is provided as a recommended program for IEP's consideration. It is expected that as overall lead in data management and access efforts, IEP will provide the necessary and specific program details for implementation. It will be CAMP's role to ensure that specific data relevant to meeting CAMP's goals are included and accessible in IEP's database. IEP is currently acquiring and managing these data, particularly for striped bass, American shad, white sturgeon, and green sturgeon. Making these population status data readily available to CAMP staff on a regular basis, and making any Delta-related data available to evaluate long-term effects of action categories on striped bass, will be CAMP-related needs. In terms of salmon and steelhead monitoring data from upstream watersheds, however, IEP is only beginning to consider what role it may play in upper watershed data acquisition, management, and access. It may be necessary for CAMP to provide a greater role in data acquisition, management, and access for these species in relation to upstream watersheds.

### **Archived Data**

One of CAMP's goals is to support the development of a data management and access program that meets the needs of the assessment portion of the program. Original data files will be archived on IEP or individual agency file servers that are networked with the IEP data warehouse. The data warehouse should have direct access to these archived files. The archived files will have



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**Figure 6-1**  
**A Conceptualization of the Data Management**  
**and Data Access Program**

metadata and file format descriptions and protocols. In many cases, original data needed for CAMP may not be in computer format, thus requiring data entry, verification, and formatting before archiving. In most cases, the monitoring agency should maintain the data archives, including updates as necessary from continuing or new surveys. It will be the responsibility of that agency to ensure that data are accessible to the central data warehouse. In some cases, it may be necessary to keep original archived data directly available to the data warehouse. In all cases, the data warehouse should have direct access to the file servers on which the archived data are maintained.

## **Data Warehouse**

A data warehouse is special database of information needed by end users and decision makers. It is made up of specific elements and reformatted elements of original data and information. A data warehouse is populated with external data from outside or internal flat (ASCII or other tabular format) files through data extraction and transformation programs. A data warehouse can also be populated with text, spatial (GIS), and multimedia data (e.g., maps, charts, digitized images, photos, audio and video clips, and reports). The data can then be viewed, queried, or downloaded to provide users with data sets in specified formats. Data can be preprocessed or analyzed for the user. Reports can also be generated with tools available to the data warehouse. Users can navigate through the warehouse, execute queries, and build reports from remote workstations.

An IEP data warehouse would make available to end users the breadth of data collected by agencies in the Bay/Delta and its watershed over the past 30+ years. Not just flat files of tabular data, or original data formats, but special reformatted data that meet the specific tabular or relational needs of the end users would be necessary.

To meet CAMP needs, data would best be organized first by species, then by watershed, and then by action category (where appropriate). CAMP will use population status data for the four races of chinook salmon, steelhead, striped bass, American shad, white sturgeon, and green sturgeon. Only for the chinook salmon races would population data be necessary from tributary watersheds, hatcheries, and the Pacific Ocean; chinook salmon doubling goals are based in part on the cumulative escapement estimates from numerous watersheds, hatchery returns, and estimates of commercial and sport fishing harvest of naturally produced fish. CAMP would also require information relative to evaluating the effectiveness of action categories on fall-, winter-, and spring-run chinook salmon and striped bass. Access to data from AFRP's 3406(b) action-specific monitoring programs, and relevant IEP Delta monitoring efforts that are directly or indirectly related to evaluating striped bass population responses to action categories, is a primary requirement for meeting CAMP's long-term needs. Meeting this latter need necessitates managing much more diverse datasets that include not only annual population data, as required to meet CAMP's first goal of long-term population monitoring, but potentially flow, temperature, habitat, survival, mortality, and other data collected to meet CAMP's second goal of evaluating action category effectiveness.

The data warehouse would comprise integrated hardware and software capabilities that provide the following set of services to the data management and access program:

- end user tools for accessing and analyzing warehouse data;
- data acquisition, retrieval, and replication capabilities from archived data;
- access to integrated, reformatted, and conditioned archived data;
- data modeling (data encoding, transformation, and cleaning);
- data quality assurance and control (some minimum standards must be established to ensure data warehouse credibility and quality<sup>2</sup>);
- data distribution (e.g., to data marts, other file servers, compact disks, floppy disks, tapes);
- data management (indexing, mapping, uploading, downloading, security, archiving, backup/recovery, process monitoring and control, and access control); and
- decision support query processing.

The data warehouse also would include the following characteristics:

- a powerful client server with large disk storage capabilities to store the vast amount of data IEP will need to store;
- extraction and transformation tools to allow warehouse administrators to populate the warehouse from outside and internal data sources; tools should include capability to scrub and map data before populating the warehouse (an example is Oracle's Discover 2000);
- large volume data loading;
- a model or map of the warehouse and its components prior to populating the warehouse, which requires input on potential user needs (an example is Oracle's Designer 2000);
- a data warehouse director with metadata and indexing (an example is HP's "Intelligent Warehouse");
- a fully functional relational database management system (RDBMS) that maintains, retrieves, and queries, as well as analyzes, presents, and reports (examples include Informix "Online", Gupta, Sybase, and Oracle, which are all fully functional Unix based

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<sup>2</sup> For many original databases, cleaning and quality checking occurs in the analyses and report phases. Some data sets from Central Valley monitoring programs exist in a cleaned version only in specific end user databases in PC spreadsheet or database formats. A formal data warehouse will provide this service in a structured and sanctioned setting that ensures all end users access to "corrected" data. It will also provide feedback to the original monitoring programs to help design the programs to meet the needs of the end users.

systems; less functional software for personal computers include Access, Foxpro, Dbase, Paradox, Superbase, and Dataease);

- an Information Manager (an example is Informix's "Information Navigator", HP's OpenWarehouse Framework, or "FACET"); and
- a graphical user interface for selecting data sets, defining queries, and creating reports.

The data warehouse would be developed in components, stages, or phases to meet the sequential needs of the end users. For CAMP, components could be sequentially built for each of the key data bases (e.g. angler surveys, fish counts at dams, etc.).

### **Data Mart**

CAMP staff needs can be met with an array of standard Windows software or by a more sophisticated information management system software product, such as FACET. FACET has a limited database management system to access the Oracle type DBMS on the IEP files server and maintain summary data sets for CAMP use. It also has basic geographic mapping, statistical analysis, graphics, and table-generating capabilities.

The data mart would serve the needs of specific CAMP users by formatting and storing specific data from the data warehouse to meet the needs of the user. This allows user access to specific sets of reformatted or analyzed data, from which to query or report with control over user access. Internet access to the data warehouse could be provided by a data mart that meets the needs of the users. The CAMP data mart should provide very specific summary data and presentation and reporting tools specifically designed to meet CAMP needs. The data mart should be designed with the specific user group needs in mind, with specific summary data sets and standard reports that are automatically updated with new data entering the data warehouse.

A data mart should have some of the following general capabilities:

- a data directory and index (end-user catalogue);
- tailored data acquisition;
- a graphic user interface with front end user tools;
- a managed query environment for querying data available (possibly through access to the RDBMS of the data warehouse);
- data downloading;

- period of record of the data,
- geographic boundaries or location of study/survey,
- parameters measured,
- sampling/survey design,
- sampling/survey locations (lat and long),
- field/lab/data protocols,
- references, and
- descriptors (key words).

CAMP has already made inroads in identifying existing and proposed monitoring programs and databases based on existing data (see Appendix D). The type of information relevant to CAMP (monitoring needs described in Chapters 3 and 4 and summarized in Chapter 5) would need to be specifically defined in the CAMP Implementation Plan and integrated into the IEP database. The necessary information would come from selected miscellaneous monitoring programs and 3406(b) action-specific, short-term monitoring programs. The specifics of many of these monitoring programs are not available, but during the next year it is expected that such programs will be defined and incorporated into CAMP. Nearly all of the relevant monitoring programs would be conducted by Service, DFG, or IEP biologists.

## **DATA REPORTING PROCESS**

CAMP will need to provide progress reports to Congress on a regular basis. These progress reports will be available to IEP, AFRP, Reclamation, DFG, other agencies, and stakeholder groups. Although these reports will summarize ongoing CAMP activities and results, additional data reporting activities will be needed on a consistent basis to optimize coordination between fisheries management agencies, particularly between the Service, Reclamation, National Marine Fisheries Service, DFG, IEP, and AFRP, and to ensure that all available data can be used by participating agencies for their own, sometimes differing, uses.

As monitoring data are collected and stored in the data warehouse, these data will be made available through the IEP data warehouse via the Internet. Data reports are envisioned every other year for the first 10 years of CAMP, and every 5 years thereafter. The data reports will facilitate the development of the progress reports to Congress and will provide useful preliminary information on anadromous species population trends and action category effectiveness. The reports will provide information in a hierarchical fashion first by CAMP Goal #1 or #2, second by species, and third by watershed (for CAMP Goal #1 where relevant) or by action category (for CAMP Goal #2).

The frequency of reporting has been developed to facilitate adaptive management strategies by the Service for CAMP and other programs. The CAMP-related data, especially those collected during the first 10 years, will provide valuable information for designing future monitoring programs

and making modifications to existing programs. It is expected that many long-term monitoring programs and every CVPIA action will be implemented during the next 10 years. Major modifications to CAMP could occur during this period in response to implementation of these other programs and CVPIA actions; relatively few changes would be expected after the initial 10-year period.

## **Recommendations for Phase II Implementation Plan**

that describes the characteristics of a "data warehouse" housed by IEP, outlines potential data organization formats, and suggests potential hardware and software that could meet the needs of CAMP and other users.

The Implementation Plan should:

- finalize watershed selection recommendations for monitoring chinook salmon;
- present funding decisions regarding existing monitoring programs scheduled for termination on which CAMP is dependent;
- validate or modify duration of time CAMP must monitor each species to adequately assess achieving doubling goals;
- provide detailed species- and watershed-specific "prescriptions", in close consultation with AFRP staff, that can provide guidance for implementing monitoring programs;
- further develop process (funding, staffing, responsibilities, accessibility, database QA/QC, GIS needs, and software and hardware) for data formatting, entry, storage, retrieval, analysis, and transfer;
- specifically identify data sets necessary for CAMP;
- identify potential incentives for timely participation in data collection and transfer to the data management system;
- describe CAMP's staffing needs, responsibilities, and processes for analyzing data to assess CAMP progress toward monitoring doubling goals, reporting progress made toward monitoring and meeting doubling goals, and recommending potential changes to CAMP and/or the 3406(b) action-specific monitoring programs;
- determine the need for systematic communication among agency and other relevant entities; and
- prepare budget requirements and funding availability for initial (5 year) and long-term monitoring for recommended programs.

## **GOAL #2: ASSESSING RELATIVE EFFECTIVENESS OF ACTION CATEGORIES**

The Conceptual Plan provides general considerations and guidelines for evaluating the relative effectiveness of the four action categories. Key attributes discussed in the Conceptual Plan include the ability to geographically or temporally isolate 3406(b) action categories; the need for control

watersheds, reaches, and time periods; watershed selection considerations; major constraints to effectively evaluating the effectiveness of action categories; and reliance on other monitoring programs and databases. Implementation of specific actions included in AFRP's Restoration Plan and/or the actual implementation of actions could ultimately result in geographic separation of actions between watersheds, thereby providing opportunities for CAMP to achieve its goal of assessing the relative effectiveness of specific action categories.

An alternative to geographic isolation of action categories is to distinguish their relative effectiveness by taking advantage of temporally isolated action categories based on the reasonable assumption that not all actions included in 3406(b) will be implemented simultaneously. Lacking prioritization and an implementation schedule, and assuming that actions will be implemented opportunistically over time (i.e., when funding becomes available and participating entities agree to implementation terms), the Conceptual Plan suggests the need for the Implementation Plan to be structured to take advantage of opportunities to develop and implement short-term, site-specific monitoring that will allow the relative effectiveness of categories of actions to be evaluated.

The Implementation Plan should:

- incorporate sufficient flexibility to adapt the monitoring program to accommodate changes in the implementation schedule and to capitalize on opportunities that arise with site-specific monitoring programs;
- facilitate these opportunities by providing additional guidance on the types of data and methods that will be helpful in determining the relative effectiveness of action categories so they may be included as components of short-term, site-specific monitoring plans associated with individual actions;
- refine and implement an initial monitoring program to differentiate among categories based on conceptual criteria and suggestions included in the Conceptual Plan;
- finalize watershed selection recommendations for evaluating action category effectiveness on chinook salmon;
- consider non-CVPIA actions in watershed selection recommendations;
- present funding decisions regarding existing monitoring programs scheduled for termination on which CAMP is dependent;
- validate or modify duration of time CAMP must monitor target species to adequately assess action category effectiveness;
- provide detailed species- and watershed-specific "prescriptions", in close consultation with AFRP staff, that can provide guidance for implementing monitoring programs;



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## Chapter 8. Citations

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#### PERSONAL COMMUNICATIONS

- Kohlhorst, David. Fisheries biologist. California Department of Fish and Game, Stockton, CA. July 6, 1995 - meeting.
- McEwan, D. Fisheries biologist. California Department of Fish and Game, Sacramento, CA. October 18, 1995 - telephone conversation.
- Mills, Terry. Senior biologist. California Department of Fish and Game, Inland Fisheries Division, Sacramento, CA. October 1995 and January 1996 - written comments.
- Stevens, Don. Fisheries biologist. California Department of Fish and Game, Stockton, CA. July 6, 1995 - meeting.



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## **Chapter 9. Acknowledgments**

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### **CONCEPTUAL PLAN DEVELOPMENT**

The CAMP Conceptual Plan was prepared by the CAMP Project Team under the direction of Mr. James McKevitt, CAMP's Program Manager with the Service's Central Valley Fish and Wildlife Restoration Program Office, and Mr. Larry Puckett, DFG's representative with the Central Valley Fish and Wildlife Restoration Program Office. The following contracting team comprised of Montgomery Watson, Jones & Stokes Associates, and CH2M Hill staff provided technical assistance in preparing the Conceptual Plan.

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# CAMP Conceptual Plan for Wildlife

## **Appendix A. CAMP Conceptual Plan for Wildlife**

Section 3406(b)(22) of the Central Valley Project Improvement Act (CVPIA) provides incentives as the Secretary of the Interior determines are appropriate or necessary, consistent with CVPIA goals and objectives, to encourage farmers to participate in a program whereby farmers will keep fields flooded during appropriate time periods to create and maintain waterfowl habitat. This provision will be terminated by 2002.

Participants in the program, as a part of their mutually acceptable agreement with the U.S. Department of the Interior, will grant limited access to their property for purposes of monitoring, evaluation, and compliance for the term of the agreement. Information compiled as a result of monitoring the program will be included in an annual report that summarizes water use, participating acreage, locations, fish and wildlife benefits, and a water supply enhancement. This report will be provided to the Comprehensive Assessment and Monitoring Program (CAMP) for all CVPIA implementation programs.

# Data Collection Procedures for Developing CAMP

## Appendix B. Data Collection Procedures for Developing CAMP

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### GENERAL OVERVIEW

Information needed for developing CAMP was obtained from a variety of sources. Initially, available agency documents provided background information on existing and proposed monitoring programs and agency activities. In addition, two workshops were held with key Service, DFG, and IEP staff to increase agency understanding of CAMP goals and receive input on CAMP's direction and measurement parameters. Finally, federal, state, water district, and fisheries biologists were surveyed to identify existing monitoring programs that could provide input to CAMP. The surveys culminated in the development of a monitoring program database that can be used by CAMP staff, as well as by other agencies with monitoring responsibilities. This chapter summarizes the agency input on CAMP measurement parameters and the development of the existing monitoring program database.

### AGENCY INPUT ON CAMP METHODS AND PARAMETERS

In addition to meeting directly with Service and DFG staff, CAMP staff reviewed the Anadromous Fisheries Restoration Program's (AFRP's) *Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California* (U.S. Fish and Wildlife Service 1995a), *A Scientific Basis for Managing Central Valley Chinook Salmon and Steelhead* (California Department of Fish and Game 1995a), and *Restoring Central Valley Streams: A Plan for Action* (California Department of Fish and Game 1993). AFRP's Working Paper (U.S. Fish and Wildlife Service 1995) is only the culmination of the initial phase of development of an AFRP draft Anadromous Fish Restoration Plan and provides a technical basis for further AFRP plans and actions. AFRP's draft Restoration Plan will evaluate the implementability and reasonableness of the actions described in the AFRP Working Paper. Based on this information, a list of potential target anadromous fish populations by watershed was developed (Table B-1). Specific selection of target species and populations is presented in Chapters 3 and 4, depending on which CAMP goal (population monitoring or action category effectiveness) is being addressed.

The following sections summarize the available information collected from these meetings and documents. Information is presented even when such input was not directly related to meeting CAMP goals. It was extremely valuable during the development of this CAMP Conceptual Plan to be aware of the other major activities and parameters that could affect CAMP. Even if many concepts here

were not incorporated into the Conceptual Plan, these concepts and ideas raised important issues that needed to be considered by CAMP staff in developing the Conceptual Plan.

### **Workshops with the Service and DFG**

CAMP staff held two sets of workshops in Stockton and Sacramento (July 6 and October 11, 1995) to discuss anadromous fish restoration plans and monitoring approaches for assessing the effectiveness of the four fisheries-related categories of actions, as well as monitoring the overall doubling goals for the populations. The following are monitoring methods and parameters suggested by the Service or DFG staff from these meetings.

### **Population Abundance Methods and Parameters**

#### **Adults**

1. Mark-recapture surveys: recommended method for estimating salmon escapement and adult striped bass, white sturgeon, and green sturgeon populations.
2. Angler surveys: a typical method for estimating inland harvest of Central Valley chinook salmon, steelhead, striped bass, American shad, and sturgeon.
3. Snorkel surveys: provides indicator of population abundance, primarily for spring-run chinook salmon.
4. Dam counts: where possible, fish ladder counts provide valuable escapement numbers for salmon and steelhead.
5. Redd counts: aerial and ground surveys of salmon redds provide valuable indicators of escapement in some watersheds.

#### **Juveniles**

1. Outmigrant surveys: net and trap surveys provide information on juvenile and smolt production for salmon and steelhead, which may be related to subsequent adult escapement or effectiveness of categories of actions undertaken within watersheds to improve salmon and steelhead production. Net surveys also provide abundance estimates for striped bass, American shad, and sturgeon.
2. Hatchery stocking records: records of salmon, steelhead, and striped bass stocking in a watershed are important for evaluating the role of hatchery fish as well as determining escapement of wild fish within a watershed. Numbers and size of fish stocked, time and

Table B-1. Potential Target Populations by Watershed

Geographic Area	Fall-Run Chinook Salmon	Late Fall-Run Chinook Salmon	Spring-Run Chinook Salmon	Winter-Run Chinook Salmon	Central Valley Steelhead	Striped Bass	American Shad	White Sturgeon	Green Sturgeon
Upper Sacramento River <sup>a</sup>	x	x	x	x	x	x	x	x	x
Upper Sacramento River Tributaries:									
Clear Creek	x	x	x		x				
Cow Creek	x				x				
Bear Creek	x				x				
Cottonwood Creek	x	x	x		x				
Battle Creek	x	x	x	x	x				
Paynes Creek	x								
Antelope Creek	x	x	x		x				
Elder Creek	x				x				
Mill Creek	x	x	x		x				
Thomes Creek	x		x		x				
Deer Creek	x	x	x		x				
Stony Creek	x	x							
Big Chico Creek	x	x	x		x				
Butte Creek	x	x	x		x				
Miscellaneous Small Tributaries	x				x				

Table B-1. Continued

Geographic Area	Fall-Run Chinook Salmon	Late Fall-Run Chinook Salmon	Spring-Run Chinook Salmon	Winter-Run Chinook Salmon	Central Valley Steelhead	Striped Bass	American Shad	White Sturgeon	Green Sturgeon
Lower Sacramento River <sup>b</sup>	x	x	x	x	x	x	x	x	x
Lower Sacramento River Tributaries:									
Feather River	x		x		x		x	x	
Yuba River	x				x		x		
Bear River	x				x				
American River	x				x		x		
Mokelumne River	x				x		x		
Consumnes River	x				x				
San Joaquin River and Tributaries:									
Merced River	x								
Tuolumne River	x								
Stanislaus River	x								
Lower San Joaquin River	x					x	x	x	
Calaveras River				x					
Delta	x	x	x	x	x	x	x	x	x

## Notes:

<sup>a</sup> From Red Bluff Diversion Dam upstream to Keswick Dam.<sup>b</sup> Below Red Bluff Diversion Dam.

Table does not include minor or infrequent occurrences of species in watersheds.

place, and conditions are important when evaluating hatchery contributions to escapement and effects on wild fish.

3. Seasonal trawl surveys in the Delta: provide key abundance index information on anadromous fishes, primarily chinook salmon, striped bass, and American shad.

### **Habitat Methods and Parameters**

1. Instream Flow Incremental Methodology (IFIM) studies: To determine flow-habitat relationships and evaluate water management actions based on these relationships.
2. Habitat monitoring: Monitoring habitat or habitat-related parameters such as flow regimes, water quality (particularly water temperature), stream channel dynamics (spawning habitat), and watershed conditions. These parameters may be important in helping to restore watershed productivity and relate fish population response to habitat conditions.

### **Specific Recommendations of AFRP Staff**

CAMP staff met with AFRP staff as a follow-up to the workshops to discuss specific recommendations of the AFRP staff on CAMP parameters. The following is a list of these recommendations:

1. Continue comprehensive monitoring of chinook salmon escapement (e.g., restore angler surveys [harvest], and continue carcass counts, redd counts, and ladder counts), and initiate or resume comprehensive monitoring of inland harvest of anadromous species.
2. Include striped bass, American shad, sturgeon, and steelhead runs in adult population monitoring.
3. Monitor ocean harvest rates on wild fish. (This requires that all hatchery fish, or a constant fraction, be marked.)
4. Monitor smolt/young production to determine the success of the respective categories of actions. (This was considered essential.)
5. Monitor habitat conditions to evaluate the effectiveness of the habitat restoration action category.
6. Monitor other factors to account for all actions: water quality, physical and chemical habitat conditions, etc.

7. Evaluate protocols and experimental/sampling designs, upgrade as necessary, and standardize. Experts in population dynamics, statistics, and sampling designs should be brought in for assistance.

### **AFRP Working Paper**

The Working Paper, distributed in May 1995 (U.S. Fish and Wildlife Service 1995a), provides specific recommendations that could lead (by virtue of CAMP's Implementation Plan) to valuable input to CAMP. Many of these elements are not directly related to CAMP but could be useful in evaluating the effectiveness of the four action categories:

1. Determine flow needs for various life stages of anadromous fish:
  - a) Measure/map physical characteristics of habitat (depth, velocity, substrate, cover, water temperature, water quality).
  - b) Determine fish response to habitat conditions.
  - c) Predict habitat value as a function of flow.
  - d) Determine instream flow requirements by species, life stage, and watershed.
2. Complete temperature models of selected watersheds in the basin.
3. Study the effects and contributions of hatchery programs:
  - a) Determine contribution of hatchery fish to populations in each watershed.
  - b) Determine the genetic integrity of natural Central Valley stocks.
  - c) Evaluate nonlethal means of separating stocks.
4. Monitor the commercial, sport, and illegal fisheries:
  - a) Determine the effect of fishing and poaching on spawning escapement (by size and age).
  - b) Determine effects of fishing on spawning stocks and recruitment.
  - c) Monitor commercial and sportfishing river and ocean harvest.
5. Identify spawning habitat of sturgeon.

6. Evaluate the effectiveness of pulsed flows on migration patterns of adult and juvenile anadromous fish.
7. Evaluate the effects of reservoir releases on river water temperatures.
8. Monitor water quality.
9. Assess the benefits of spawning and rearing habitat improvements.
10. Evaluate screening needs at existing diversions.

### **A Scientific Basis for Managing Needs for Central Valley Chinook Salmon and Steelhead**

The third draft of DFG's Inland Fisheries Division report on monitoring and research needs (California Department of Fish and Game 1995a) was provided to CAMP staff by DFG as input for determining parameters for CAMP to address. In this report, DFG proposes to redouble its effort to maintain high-quality population estimates, monitor harvests, develop a better understanding of juvenile fish life history, and evaluate and monitor habitat. To accomplish these goals, DFG recognizes that it will need to identify new funding or redirect existing funding, and swiftly implement a comprehensive long-term monitoring and research program. The report further states that restoration goals cannot be met unless DFG develops, supports, and implements a comprehensive monitoring and research program directed at Central Valley salmon and steelhead. The plan calls for partnerships with other programs including CAMP.

The report also summarizes the recommendations of the Bay-Delta Water Quality Control Plan and the DFG strategic plan, both of which are described in the following sections. The report has the following specific recommendations that could pertain directly or indirectly to CAMP:

1. Classify Sacramento fall-run chinook salmon, Sacramento late fall-run chinook salmon, Sacramento winter-run chinook salmon, Sacramento spring-run chinook salmon, San Joaquin fall-run chinook salmon, and Central Valley winter steelhead as evolutionarily significant units (ESUs).
2. Determine the contribution of hatchery fish to production of naturally spawning fish.
3. Determine other effects of hatcheries on natural populations of salmon and steelhead, such as genetic diversity changes, harvest effects, and disease effects.
4. Monitor adult populations for each ESU:

- a) Monitor long-term trends in adult spawning populations through annual estimates of escapement via spawning stock surveys, ladder counts, aerial surveys, snorkel surveys, and hatchery return counts.
  - b) Monitor returns to hatcheries to provide the hatchery component to complement the naturally spawning population estimate.
  - c) Monitor fish harvested to complement the spawner return numbers.
  - d) Design and implement a comprehensive steelhead monitoring and assessment program.
5. Monitor juvenile populations, using a comprehensive Central Valley-wide approach, for the following characteristics:
- a) time and size of emigration
  - b) location and duration of juvenile rearing in rivers and Delta
  - c) timing of Delta and ocean entry
  - d) growth, production, and abundance indices
  - e) survival through specific river reaches
  - f) effects of export facilities, in-channel depletions, channel modifications, reverse flows in the Delta, unscreened diversions, and predation at water facilities
6. Monitor physical habitat for the following characteristics:
- a) spawning gravel availability and condition
  - b) rearing habitat quantity and quality
  - c) nearshore and streambank conditions
  - d) watershed stability
  - e) stream hydrology and geomorphic processes
  - f) other physical and biological capacity factors
  - g) unscreened diversions
7. Evaluate the following flow-related parameters:

- a) water quantity, timing, and quality
  - b) flow-habitat relationships, especially temperature
  - c) reservoir-stream temperature modeling
  - d) flow fluctuations
8. Monitor harvest considering the following factors:
    - a) ocean harvest (sport and commercial)
    - b) Central Valley angler surveys (inland sport harvest)
    - c) illegal harvest (not considered a critical element)
  9. Conduct and expand coded-wire tagging programs (release tagged hatchery and naturally produced juvenile salmon and steelhead under varying conditions in different watersheds to evaluate survival to the Delta, ocean, and spawning rivers).
  10. Evaluate the genetic diversity of basin salmon and steelhead populations.
    - a) Determine the extent of reproductive isolation by analyzing movements of tagged fish, recolonizing rates of other populations, measurements of genetic differences between populations, and evaluation of the efficacy of natural barriers.
  11. Focus monitoring and research at the stock level.
  12. Determine barriers or impediments to upstream migration of spawners in basin.

### **DFG Strategic Plan**

DFG's strategic plan (California Department of Fish and Game 1995b) has a number of recommendations that could directly or indirectly pertain to CAMP. Although meant as goals and objectives for DFG, they also could be important to CAMP goals and objectives as CAMP should be developed in cooperation with DFG. DFG's plan calls specifically for monitoring in the following areas that pertain to CAMP:

1. Establish policy and a process for data gathering and exchange.
2. Determine habitats at risk.
3. Develop adequate databases.

4. Monitor water diversions to ensure compliance.
5. Continue and complete instream flow studies.
6. Determine take and evaluate effect of take of anadromous fish at water diversions.
7. Identify and collect baseline biological information on key species and biological communities.
8. Develop a ranking system for species and habitat research based on the need and amount of current information.
9. Improve expertise in population dynamics.

### **Bay-Delta Water Quality Control Plan**

The May 1995 Bay-Delta Water Quality Control Plan (California State Water Resources Control Board 1995) includes recommendations that could pertain to CAMP's goal of evaluating the effectiveness of the four action categories:

1. Monitor physical, chemical, and biological parameters to determine compliance with water quality objectives.
2. Maintain consistent, long-term records of trends in estuary water quality and the abundance and distribution of phytoplankton, zooplankton, aquatic invertebrates, and fish populations.
3. Develop and improve predictive assessment capabilities to evaluate effects of water projects and other factors.
4. Continue the evaluation and modification of sampling gear, equipment, technology, and methods.

### **Restoring Central Valley Streams: A Plan for Action**

DFG's Plan for Action (California Department of Fish and Game 1993) provides a number of recommendations that may be applicable to CAMP:

1. Determine minimum carryover needs and associated operational criteria in Shasta, Folsom, and Oroville reservoirs to maintain suitable year-round temperatures in rivers below impoundments.

2. Evaluate effects of fluctuating flows due to power peaking, and determine ramping rate criteria below basin dams.
3. Conduct and complete instream flow studies.
4. Conduct and complete spawning, rearing, and migration habitat restoration on basin rivers.
5. Conduct juvenile rearing and adult escapement studies.
6. Evaluate fish passage problems on basin rivers.
7. Monitor fish passage on basin rivers.
8. Conduct hydrologic and sediment studies on selected basin rivers.
9. Develop hydrologic models on basin rivers.
10. Monitor flows and temperatures on basin rivers.
11. Evaluate flow/temperature relationships on basin rivers.
12. Evaluate benefits of increased flows on migrating adult anadromous salmon and steelhead.
13. Determine spawning gravel limitations and requirements in Central Valley rivers.
14. Evaluate performance of implemented structural remedies.
15. Monitor gravel restoration in rivers.
16. Monitor toxins in river waters.
17. Develop a water temperature model for the San Joaquin River.
18. Develop a dissolved oxygen model for the San Joaquin River near Stockton.
19. Complete the assessment of unscreened diversions in the basin.
20. Evaluate alternative methods of providing temperature controls on selected basin reservoirs.
21. Determine riparian restoration and preservation areas.
22. Conduct smolt survival studies on selected rivers in the basin.

## SUMMARY OF EXISTING MONITORING PROGRAMS

### Introduction

This section is intended primarily to identify and summarize existing anadromous fisheries monitoring programs in the Central Valley that are pertinent to CAMP goals. In some cases, completed monitoring programs are also included in the analyses because data for these programs were readily available, these programs provided a fundamental basis for developing 1967-1991 population estimates, and these programs could influence CAMP's selection of watersheds for detailed monitoring. The focus of the effort was to identify monitoring programs that could provide information on the target species, races, lifestages, and geographic areas necessary for evaluating the effectiveness of CVPIA either to meet anadromous fishery doubling goals set forth by AFRP or to evaluate the relative success of each of the four fisheries-related action categories in meeting the doubling goals.

For the most part, monitoring programs that estimate the abundance of adult anadromous fish (and juvenile American shad) are relevant to CAMP because these are the lifestages used to measure the AFRP doubling goals. All other types of monitoring programs, such as those for non-adult lifestages or those that monitor various habitat parameters, are not needed to determine whether doubling goals are met. The first goal of CAMP is not to address *why* doubling was or was not achieved, but *whether* doubling was or was not achieved. These other monitoring programs become important, however, in meeting CAMP's second goal, which is to assess the general effects of the four fisheries action categories. This goal begins to address why doubling was or was not achieved, but does so only on a fairly broad basis (within the four fisheries action categories). Addressing this goal, even generally, requires greater specificity in regard to the parameters that affect long-term population trends. Consequently, other monitoring programs that provide information on non-adult lifestages or site- and action-specific effects then can be important in meeting this CAMP goal.

Existing federal, state, and local anadromous fisheries monitoring programs generally are structured around species, watersheds, and water resource projects and, as such, may not entirely meet the overall goals of CAMP. In designing a practical and cost-effective monitoring program for CAMP, however, an understanding and incorporation of these programs is imperative. Many of these programs are relevant to CAMP, but are conducted over a short time span rather than the long-term period required by CAMP. It is expected, however, that existing programs will contribute a substantial portion of the final CAMP effort.

## **Methods**

### **Obtain Monitoring Program Information**

Monitoring program information was obtained primarily by reviewing readily available agency monitoring reports; interviewing federal, state, water district, and consulting fisheries biologists and program managers by telephone; and receiving input at several meetings and workshops. Some additional information was gathered by briefly reviewing files at the DFG Region 2 headquarters in Rancho Cordova. An attempt was made to identify programs in each Central Valley watershed with an anadromous fish population.

The steps involved in gathering monitoring program information varied depending on the specific program and the information at hand, but generally were as follows:

1. A monitoring program profile form was developed to assist the project team in systematically gathering information on existing monitoring programs. Information on past and future monitoring programs also was gathered if readily available from contacts. Key data included in the profile forms were watershed, target species and lifestages, monitoring goals, geographic area, program duration, parameters measured, sampling design and type, and database structure (Appendix D, bound separately).
2. Monitoring program reports were gathered from various sources, including agency biologists, DFG files, and the Jones & Stokes Associates fisheries library.
3. Profile forms were filled out as completely as possible based on the information contained in the monitoring program reports.
4. The project team developed a list of individuals to be contacted for further information on specific monitoring programs (Table B-2).
5. A memorandum and a copy of the monitoring program profile form were faxed or mailed to identified individuals briefly explaining CAMP and requesting information as identified on the form. In some instances, a telephone call was made first to an agency or individual to verify or identify the appropriate contact for a specific monitoring program. Some forms were completed over the telephone and additional correspondence was unnecessary.
6. After reviewing any available monitoring program reports and profile forms returned by the contacts, a follow-up telephone call was made to each contact if additional information was necessary to complete the form. Some profile forms remain incomplete, however, because of difficulty in contacting agency biologists.

## Review, Screen, and Select Monitoring Programs

After the information gathering process was completed, monitoring programs were either selected or rejected for further consideration in developing the Conceptual Plan and for GIS mapping, based on their relevancy for meeting CAMP objectives. The following set of criteria was developed to aid this screening process:

1. The monitoring program or study should be directed primarily toward monitoring anadromous fish population variables that could ultimately be used to determine whether populations are doubled on a long-term basis.
2. The monitoring program or study, if directed toward research, restoration, or enhancement, should have components that can ultimately be used to distinguish between the four broad action categories, preferably by monitoring the effects directly on anadromous fish population abundance.
3. The monitoring program or study must last more than 1 year, or if short term, must be comprehensive (e.g., covering a broad geographical area).

The first criterion was directed at retaining programs that monitored anadromous fish population lifestages relevant for determining doubling (i.e., juveniles for shad and adults for all other species). Programs that monitored other variables important in determining population estimates were also retained (e.g., the percentage of steelhead harvested in the Sacramento River based on RBDD counts). These programs are largely the responsibility of DFG.

The second criterion was directed at retaining programs that could provide information to assist in assessing the effectiveness of the four action categories. These programs were much more diverse and included monitoring programs for lifestages other than adults and included numerous habitat monitoring programs. Juvenile lifestages and any juvenile production estimates were considered to be the most important lifestage for assessing category effectiveness because juveniles can be an excellent index of watershed production. Monitoring programs that monitored only whether a habitat variable (such as gravels placed in a stream) persisted over time and did not attempt to link the restoration action to some measure of fish population change (abundance, production, survival, or mortality) were screened out. The unquantified link between habitat, as estimated by the Instream Flow Incremental Methodology (IFIM), and fish population response necessitated that these studies be excluded from further analyses.

The third criterion was directed at retaining programs that would have some measure of annual variability in the response variables and that provided more than 1 year of baseline information for assessment under CAMP. Several monitoring programs were extremely limited in their duration and, consequently, their utility in meeting CAMP goals.

Programs that met the first or second criteria and the third criterion were summarized in a spreadsheet database for use in the GIS database and mapping component of the CAMP Conceptual Plan development. The spreadsheet database of relevant monitoring programs also was used to

prepare summary tables for the Conceptual Plan. Programs that did not meet these criteria were not considered further and are not presented herein.

## Results

Existing monitoring programs identified as potentially relevant to meeting CAMP goals are identified in Tables B-3 through B-17, which are presented at the end of this appendix. Also identified are recent monitoring programs that are no longer in effect but that may provide additional data for assessing future abundance trends or the effectiveness of the four categories of actions. Each table presents key monitoring data for each target species and lifestage, including watershed, monitoring program name, monitoring methods, lead agency, program time frame, and status. Many of these programs include both adult and juvenile population monitoring and, in some cases, habitat monitoring that may be appropriate for CAMP monitoring to determine the effectiveness of the categories of actions. The goals of each of the monitoring programs are extremely variable and cannot be effectively summarized. Appendix D (bound separately), however, can be reviewed to determine specific information about any single monitoring program.

A list of contacts and their affiliations is presented in Table B-2. Table B-3 presents all relevant monitoring programs by watershed so that all monitoring programs, target species, and lifestages specific to individual watersheds or geographic areas can be readily determined.

### Population Monitoring

**Fall-Run Chinook Salmon.** The most numerous monitoring programs and most extensive records are for fall-run chinook salmon. Fall-run chinook salmon support major commercial and sport fisheries and are the most abundant and broadly distributed of all Central Valley chinook salmon races. Natural production is supplemented annually by significant numbers of salmon produced at five major hatcheries. Tables B-4 and B-5 summarize the relevant fall-run chinook salmon monitoring programs in the Central Valley for adults and juveniles, respectively.

**Adult Populations.** Assessments of Central Valley adult salmon stock have been made by obtaining estimates of adult in-river escapement, hatchery returns, inland sport harvest, and ocean commercial and sport landings from various inland and ocean fishery monitoring programs. Methods used to estimate chinook salmon escapement include ladder counts, carcass surveys, redd surveys, and hatchery counts. In-river sport harvest has been estimated from sporadic angler surveys conducted in the Sacramento River, San Joaquin River, and major tributaries. Annual ocean harvest estimates of Central Valley chinook salmon have been obtained by sampling ocean landings at several central and northern California ports. These estimates include a minor unknown fraction of late fall-, winter-, and spring-run adults. DFG has been the lead agency responsible for implementing and coordinating these monitoring programs during the baseline period.

**Juvenile Populations.** Juvenile fall-run chinook salmon populations have been monitored by a variety of sampling methods, depending on geographic location, the size of the river sampled, monitoring objectives, and the responsible agency. Methods include rotary screw trapping, beach seining, electrofishing, trawl surveys, fyke net trapping, and snorkeling surveys. DFG conducts rotary screw trapping on several tributaries, including Deer Creek, Mill Creek, Butte Creek, lower American River, and the mainstem Sacramento River at RBDD and the Glenn-Colusa Irrigation District (GCID) diversion near Hamilton City. The Service has been conducting juvenile distribution surveys using beach seining on the mainstem Sacramento River since 1981. This program is the only long-term year-round juvenile salmonid monitoring program in the upper Sacramento River. Monitoring by DFG and the Service for juvenile fall-run chinook salmon in the Delta includes various methods, such as screw trapping, beach seining, and trawl surveys.

Other long-term juvenile monitoring programs include the East Bay Municipal Utility District's (EBMUD's) programs on the Mokelumne River and Yuba County Water Agency's (YCWA's) program on the Yuba River. In the San Joaquin River system, juvenile fall-run chinook salmon lifestages have been monitored in the Tuolumne River since 1986. A comprehensive juvenile monitoring study jointly sponsored by DFG and Merced Irrigation District (MID) is currently being planned for the Merced River.

**Late Fall-Run Chinook Salmon.** Monitoring programs for late fall-run chinook salmon adults and juveniles are summarized in Tables B-6 and B-7, respectively.

Although the presence of late fall-run chinook salmon in the Sacramento River was recognized before 1970, it was not included in earlier Central Valley spawning stock inventories. Only after construction of Red Bluff Diversion Dam (RBDD) and the fish ladders was enumeration and racial separation possible.

**Adult Populations.** Fewer monitoring programs exist for late fall-run chinook salmon compared with fall-run salmon because of the race's limited geographical distribution in the Central Valley. Late fall-run chinook salmon are found almost exclusively in the mainstem and upper tributaries of the Sacramento River. A late fall-run chinook salmon run may exist in the Stanislaus River, but this is unsubstantiated (Mills pers. comm.). Monitoring of late fall-run chinook salmon has been conducted in Battle, Butte, Deer, and Mill creeks; the upper Sacramento River mainstem; and the Delta using the methods described for fall-run chinook salmon. These programs, however, have either been completed or are intermittent. The RBDD passage facilities study involves the only continuous monitoring program for late fall-run chinook salmon in the upper Sacramento River. Late fall-run chinook salmon ocean harvest is monitored in the sense that adipose clipped CWT late fall-run chinook salmon from Coleman National Fish Hatchery are sampled through the sampling program directed generically at chinook salmon.

**Juvenile Populations.** Juvenile late fall-run chinook salmon have been or are currently monitored in Battle, Butte, Deer, and Mill creeks; the upper Sacramento River; and the Delta. Monitoring methods have included beach seining, electrofishing, rotary screw trapping, fyke net trapping and trawl surveys. Except for DFG's estuarine monitoring program and the Service's fry and smolt abundance studies in the Delta, monitoring for juvenile late fall-run chinook salmon has been

Table B-2. List of Contacts and their Affiliation

Watershed	Contact	Agency/Affiliation	Notes
American River	Bratovich, Paul	Beak Consultants, Inc.	
	Castleberry, Dan	USFWS	
	Ducey, Ron	CDFG	
	Snider, Bill	CDFG	
Battle Creek	Williams, John	Watermaster, consulting hydrologist	
	Rectenwald, Harry	CDFG	
	Hoopaugh, David	CDFG	
	Steitz, Curtis	PG&E	
Battle Creek	Hill, Kathy	CDFG	
Butte Creek	Steitz, Curtis	PG&E	
Central Valley	Fisher, Frank	CDFG	
	Mills, Terry	CDFG	
	Moyle, Peter	UC Davis	
	Mullen, Jim	USGS	
	Payne, Tom	TR Payne Associates	
	Vogel, Dave	Natural Research Scientists	
	Walber, Wayne	DWR	
	Benthin, Randy	CDFG	
Clear Creek	Rectenwald, Harry	CDFG	
Clear Creek	Herrington, Jim	CDFG	
Cosumnes River	Hill, Kathy	CDFG	
	Martinez, David	The Nature Conservancy	
	Snider, Bill	CDFG	
	Steitz, Curtis	PG&E	
Cow Creek	Lenninger, Chris	Deer Creek Watershed Conservancy	
Deer Creek	Archibald, Elaine	California Urban Water	
Delta		Agencies/Agricultural Water Agencies	
	Bailey, Randy	Bailey Environmental	
	Brandes, Pat	USFWS	
	Brown, Randy	DWR	
	Buell, Jim	MWD	
	Castleberry, Dan	USFWS	
	Coulston, Pat	CDFG	
	Daniel, Dick	CALFED	
	Eichenberry, John	USFWS	
	Hansen, Chuck	Hansen Environmental	
	Hess, Lloyd	USBR	Tracy Salvage Facility
	Kjelson, Marty	USFWS	
	Kohlhorst, Dave	CDFG	
	Miller, Lee	CDFG	
	Mills, Terry	CDFG	
	Moyle, Peter	UC Davis	
	Sommer, Ted	DWR	
	Stevens, Don	CDFG	
	Wulschlegger, John	USFWS	
Feather River	Calza, Carol	USCOE	
	Castleberry, Dan	USFWS	
	Harvey, Colleen	CDFG	
	Nelson, John	CDFG	
	Sommer, Ted	DWR	
	Villa, Nick	CDFG	
	West, Terry	CDFG	
Mill Creek	Hanna, Judd	Mill Creek Watershed Conservancy	
Mokelumne River	Miyamoto, Joe	EBMUD	
Ocean Harvest	Baracco, Alan	CDFG	
Upper Sacramento River	Gard, Mark	USFWS	Basin IFIMs
	Benthin, Randy	CDFG	
	Birk, Serg	USBR	Upper basin
	Demko, Doug	S.P. Cramer & Associates, Inc.	GCID
	Hansen, Chuck	Hansen Environmental	GCID

Table B-2. Continued

Watershed	Contact	Agency/Affiliation	Notes
Upper Sacramento River	Hinton, Ralph	DWR	
	Hovekamp, Spencer	USBR	
	Johnson, Rich	USFWS	RBDD
	Maslin, Paul	Chico State University	
	Rectenwald, Harry	CDFG	Upper basin
	Steitz, Curtis	PG&E	Upper basin
	Stodolski, Max	USBR	RBDD
	Tenney, Van	Glenn-Colusa Irrigation District	GCID
	Villa, Nick	CDFG	Upper basin, including GCID
	Ward, Paul	CDFG	Upper basin
Lower Sacramento River	Jackson, Terry	CDFG	
	Odenweller, Dan	CDFG	
	Wixom, Lynn	CDFG	
San Joaquin River	Bailey, Randy	Bailey Environmental	Entire basin
	Baldrige, Jean	Trihey & Assoc.	Entire basin
	Brown, Larry	USGS	Entire basin
	Cross, Peter	USFWS	
	Dubrovski, Neil	USGS	Entire basin
	Hansen, Dave	Ecological Analysts	Entire basin
	Lentz, Ken	USBR	Entire basin
	Lifton, Wayne	Entrix	Entire basin
	Loudermilk, Bill	CDFG	Entire basin
	Raines, Rich	USBR	
	Rich, Alice	AA Rich & Associates	Entire basin
	Taylor, Gary	USFWS	
	Thomas, Jeff	USFWS	
	Brandes, Pat	USFWS	
	Demko, Doug	S.P. Cramer & Associates, Inc.	
Lower San Joaquin River	Brandes, Pat	USFWS	
	Li, Stacy	Independent Consultant	
Tuolumne River	Ford, Tim	Turlock ID	
	Ligon, Frank	Ecological Analysts	
	Taylor, Tom	Trihey & Assoc.	
	Thomas, Jeff	USFWS	IFIM
Yuba River	Calza, Carol	Army Corps of Engineers	
	Castleberry, Dan	USFWS	
	Cramer, Steve	South Brophy Water District	
	Cramer, Steve	S.P. Cramer & Associates, Inc.	
	Mitchell, Bill	Jones & Stokes Associates	
	Nelson, John	CDFG	
	Rose, Dave	CDFG	
	Villa, Nick	CDFG	

intermittent. Monitoring of juvenile salmon in tributaries of the upper mainstem Sacramento River started in 1993.

**Winter-Run Chinook Salmon.** Adult and juvenile winter-run chinook salmon monitoring programs are summarized in Tables B-8 and B-9, respectively.

Ladder counts at RBDD, in combination with aerial redd surveys, have been used to monitor winter-run chinook salmon abundance in the upper mainstem Sacramento River since 1967.

**Adult Populations.** In-river escapement of adult winter-run chinook salmon has been monitored in the upper mainstem Sacramento River by ladder counts at RBDD, aerial redd surveys, and carcass surveys. The Service has conducted underwater surveys of winter-run salmon redds in the Redding area using scuba since 1987. The Service began making ladder counts of adult winter-run at the Coleman National Fish Hatchery Barrier Dam in 1995. Some returning adults are trapped each year to sustain a hatchery program for winter-run chinook salmon at Coleman National Fish Hatchery. Past angler surveys provide limited information on inland sport harvest of winter-run chinook salmon. Current angling regulations protect winter-run chinook salmon during the principal upstream migration period. Ocean harvest of CWT winter-run chinook salmon is monitored similar to late fall-run chinook salmon.

**Juvenile Populations.** Monitoring of juvenile winter-run chinook salmon populations in the upper mainstem Sacramento River includes beach seining by the Service, rotary screw trapping by the Service at RBDD and by DFG and GCID at GCID's diversion near Hamilton City, and fyke net trapping by Reclamation at RBDD. Monitoring in the Delta is conducted by DFG and the Service as part of the estuarine monitoring program and the juvenile salmonid distribution and abundance studies, respectively.

**Spring-Run Chinook Salmon.** Fewer monitoring programs exist for spring-run than for fall-run chinook salmon because of the limited geographic distribution of spring-run chinook salmon in the Central Valley. Adult and juvenile spring-run salmon monitoring programs are summarized in Tables B-10 and B-11.

Spring-run chinook salmon were extirpated in the San Joaquin River basin by the late 1940s. Much of the historical spawning and rearing habitat that supported spring-run chinook salmon is no longer accessible to these fish because of impassable dams constructed at the lower limits of their summer ranges. Currently, the Feather River; upper Sacramento River; and several smaller Sacramento River tributaries, including Butte, Mill, and Deer creeks, have sustained runs of spring-run chinook salmon. Mill and Deer creeks are believed to be the most likely creeks supporting genetically pure populations of spring-run chinook salmon, but Antelope, Big Chico, and Butte creeks may support genetically pure populations, as well. The Feather River spring-run salmon stock is primarily a hatchery run and is distinguished from the fall-run salmon stock by arbitrary designation of all fish arriving at the hatchery before September 1 as spring-run salmon.

**Adult Populations.** Adult escapement of spring-run chinook salmon is estimated using methods outlined above for fall-run chinook salmon. Ongoing monitoring programs for adult spring-

run chinook salmon are conducted on Battle, Big Chico, Butte, Deer, and Mill creeks and the upper mainstem Sacramento and Feather rivers by DFG, using a combination of carcass surveys, redd surveys, snorkel surveys, ladder counts, and hatchery counts. No in-river sport harvest estimates for spring-run chinook salmon are available. Port sampling of chinook salmon landings provides a means of estimating the contribution of marked spring-run chinook salmon from Feather River Hatchery, but estimates of the contribution of natural production to the ocean fishery have not been possible, similar to other chinook salmon races.

**Juvenile Populations.** Monitoring of spring-run juvenile salmon is currently conducted by the Service at RBDD and by DFG on Butte, Mill, and Deer creeks, using rotary screw traps. As discussed above, the most comprehensive juvenile spring-run chinook monitoring program is the Service's Sacramento River salmonid beach seining program. Juvenile spring-run chinook salmon are often captured as a result of fall-run chinook salmon monitoring programs.

**Steelhead.** Adult and juvenile steelhead monitoring programs are summarized in Tables B-12 and B-13. Steelhead runs in the Central Valley are largely sustained by hatchery production. Monitoring programs for steelhead in the Central Valley are very limited and usually associated with hatchery programs or chinook salmon monitoring programs. The only long-term record of steelhead run size is from ladder counts at RBDD beginning in 1967.

**Adult Populations.** Annual monitoring programs for adult steelhead are limited to ladder counts at RBDD on the upper Sacramento River and Woodbridge Dam on the Mokelumne River, Nimbus Hatchery on the lower American River, Feather River Hatchery on the Feather River, and Coleman National Fish Hatchery on Battle Creek. An angler survey program run by DFG provides additional information on catch effort, but this program has been terminated, at least for the time being.

**Juvenile Populations.** Monitoring of juvenile steelhead populations is generally conducted as part of other juvenile salmonid monitoring programs. Rotary screw trapping is currently conducted in the lower American River, upper mainstem Sacramento River, Mokelumne River, and Butte Creek and is planned for the Feather River. Beach seining, snorkeling, and electrofishing surveys were conducted in Battle Creek in 1989.

**Striped Bass.** Striped bass are extensively monitored in the Delta and the San Francisco Bay Estuary. Both adult and juvenile monitoring programs for striped bass are summarized in Table B-14.

**Adult Populations.** DFG has been monitoring adult striped bass populations in the Delta since 1969 using mark-recapture techniques and angler surveys. In 1995, EBMUD conducted striped bass monitoring studies at Woodbridge Dam on the Mokelumne River as part of a juvenile salmonid predator study.

**Juvenile Populations.** Juvenile striped bass have been monitored in the Delta and San Francisco Bay by DFG using fall midwater trawls since 1967 and summer tow net surveys since 1959. Since 1980, DFG has monitored fish abundance and distribution in the Delta using electrofishing techniques.

**American Shad.** Table B-15 summarizes existing monitoring programs for American shad.

**Adult Populations.** In the 1970s, DFG conducted creel surveys in the Delta and major Sacramento River tributaries for 8 years to estimate annual harvest of American shad and other anadromous species. Systemwide government population estimates, however, are available only for 1976 and 1977.

**Juvenile Populations.** Since 1967, American shad juveniles have been monitored in the Delta by DFG using midwater trawls as part of DFG's estuarine monitoring program. Rotary screw trapping of American shad larvae has been conducted on the American River by DFG since 1992 as part of the lower American River emigration survey.

**White Sturgeon and Green Sturgeon.** Table B-16 summarizes the existing monitoring programs for white sturgeon and green sturgeon.

**Adult Populations.** Monitoring for adult sturgeon in the Central Valley is limited to ongoing DFG tagging studies in the Delta as part of DFG's estuarine monitoring program.

**Juvenile Populations.** Since 1980, juvenile sturgeon have been monitored in the Delta by DFG using trawl and electrofishing surveys as part of the resident fisheries inventory program. Rotary screw traps at GCID's diversion on the mainstem Sacramento River have also enabled monitoring of juvenile sturgeon abundance since 1991.

### **Habitat Monitoring**

Tables B-4 through B-16 present a variety of habitat studies conducted in watersheds or geographic areas where fish population monitoring has been implemented. These studies may provide useful information for evaluating primarily habitat changes resulting from implementing restoration actions under the four action categories. For example, predictions of changes in physical habitat created by flow, channel, or riparian restoration actions may be used with fish population monitoring results to evaluate the overall effectiveness of the four categories of restoration actions.

Long-term habitat monitoring in the watersheds and geographic areas where population monitoring has been implemented includes records of daily flow and water temperature maintained by the U.S. Geologic Survey and California Department of Water Resources at selected stations (Table B-17). These records have provided the basis for some of the habitat analyses described above.

## **Existing and Proposed Population Abundance Monitoring by Geographic Area**

DFG recently identified the need for a comprehensive monitoring and research program that would provide fishery managers with high-quality data for effectively managing Central Valley chinook salmon and steelhead resources (California Department of Fish and Game 1995a). The need for a comprehensive monitoring and research program is based on consideration of various issues, including ecosystem management, biodiversity, public trust, management partnerships, habitat restoration, evolutionarily significant units, and coordination with CVPIA.

Considerable overlap exists between the monitoring needs identified by DFG and those identified for CAMP. DFG identified several key monitoring and research activities for managing Central Valley adult salmon and steelhead populations, including annual monitoring of in-river escapement, inland sport harvest, ocean commercial and sport harvest, and inland and ocean recovery of CWT salmon. DFG prioritized the need for these activities on a geographic basis and indicated whether these activities are partially funded or unfunded. These activities and their geographic distribution are discussed below in relation to the existing monitoring programs identified as relevant to CAMP needs.

### **Fall-Run Chinook Salmon**

**Spawning Escapement.** Natural spawning areas and hatcheries receiving high priority for monitoring of in-river escapement of adult fall-run chinook salmon are the upper Sacramento River between Keswick Dam and Hamilton City, Battle Creek, Butte Creek, Clear Creek, Cow Creek, Deer Creek, Mill Creek, Feather River, Yuba River, American River, Coleman National Fish Hatchery, Feather River Hatchery, Nimbus Hatchery, Mokelumne Hatchery, Stanislaus River, Tuolumne River, Merced River, and Merced Hatchery. Long-term monitoring of fall-run chinook salmon escapement has been conducted in most of the major Sacramento and San Joaquin River tributaries and hatcheries listed above. Except for Deer Creek and Mill Creek, records of annual run size on the smaller Sacramento River tributaries are incomplete or nonexistent, although recent monitoring efforts have been initiated on Battle Creek and Butte Creek. Carcass surveys, ladder counts, aerial surveys, snorkel surveys, and hatchery counts currently in use are the monitoring methods needed to meet DFG's and CAMP's monitoring objectives.

**Inland Sport Harvest.** High-priority streams for monitoring of inland sport harvest of fall-run chinook salmon are the Sacramento River between Keswick Dam and Chipps Island, and the Feather, Yuba, American, and San Joaquin rivers. No comprehensive measure of inland sport catches has been made consistently; angler surveys have been short term (less than 5 years) or fragmented in time and often limited to small geographic areas. Crude estimates of annual harvest of chinook salmon have been developed for the mainstem Sacramento River based on ladder counts at RBDD, annual harvest estimates for the reach above RBDD, and a regression between harvest rate above RBDD and total Sacramento River harvest. Recently, DFG conducted year-round angler surveys in the Sacramento, Feather, Yuba, and American rivers from January 1991 through December 1994.

**Ocean Commercial and Sport Harvest.** Monitoring ocean commercial and sport harvests of chinook salmon will continue to be an essential component for assessing adult populations

and meeting DFG's and CAMP's monitoring needs. Although limited tagging of hatchery salmon is presently conducted, no comprehensive effort has been made to discriminate individual salmon stocks caught in the ocean by stream or hatchery of origin.

**Coded-Wire Tagging Program.** The Service and DFG have recommended establishing a long-term comprehensive coded-wire tagging program for Central Valley hatcheries to monitor fish populations and fishery harvest. Such a program would require significant effort to recover tagged fish in the ocean and inland fisheries, during spawning stock surveys, and at the hatcheries and other sampling facilities. High-priority streams and hatcheries identified by DFG for continuing or improving CWT recovery efforts generally correspond to the streams and hatcheries identified above under "Spawning Escapement" and "Inland Sport Harvest".

No comprehensive or coordinated program for marking and recovery of hatchery or natural stocks currently exists. The most consistent effort to recover CWT hatchery salmon occurs at Central Valley hatcheries.

### **Late Fall-Run Chinook Salmon**

**Spawning Escapement.** High-priority streams for monitoring late fall-run chinook salmon adult populations are the upper Sacramento River between Keswick Dam and Hamilton City, and Battle Creek. Ladder counts of late fall-run chinook salmon have been made in the upper Sacramento River at RBDD since 1967, but estimates of spawning adults below the dam have been limited. Spawning escapement surveys on Battle Creek have been intermittent. DFG initiated annual ladder counts and carcass surveys in Battle Creek in 1993 to estimate late fall-run chinook salmon run size.

**Inland Sport Harvest.** DFG recommended that angler surveys for estimating inland sport harvest of late fall-run chinook salmon focus on the Sacramento River between Keswick Dam and Chipps Island. The comments made above about inland harvest estimates of fall-run chinook salmon generally apply to late fall-run chinook salmon.

**Ocean Commercial and Sport Harvest.** Because of an inability to discriminate between individual races or stocks of salmon in ocean catches, estimates of the contribution of naturally spawning late fall-run chinook salmon to the ocean commercial and sport fisheries have not been possible.

**Coded-Wire Tagging Program.** The Service currently marks and releases hundreds of thousands of late fall-run chinook salmon each year from Coleman National Fish Hatchery. This program provides information important for evaluating the ocean and inland fishery contributions of late fall-run chinook salmon.

### **Winter-Run Chinook Salmon**

**Spawning Escapement.** High-priority streams for monitoring winter-run chinook salmon adult populations are the upper Sacramento River between Keswick Dam and Hamilton City,

Battle Creek, and Coleman National Fish Hatchery. Annual counts of winter-run chinook salmon became possible following the construction and operation of RBDD and fish ladders in 1967. Aerial redd counts above and below the dam have been used to supplement ladder counts and generate total estimates of winter-run spawning escapement. DFG initiated annual ladder counts and carcass surveys in Battle Creek in 1995 to estimate winter-run chinook salmon run size. The artificial propagation program at Coleman National Fish Hatchery produces records of the number of winter-run adults trapped and juveniles produced annually.

**Inland Sport Harvest.** The comments made above about inland sport harvest estimates of fall-run chinook salmon generally apply to spring-run chinook salmon. Monitoring of inland harvest of winter-run chinook salmon is currently not necessary because of protective regulations now in effect.

**Ocean Commercial and Sport Harvest.** Because of an inability to discriminate individual races or stocks of salmon in ocean catches, accurate estimates of the contribution of winter-run chinook salmon to the ocean commercial and sport fisheries have not been possible until recently. CWT winter-run chinook have been released since 1992, providing the capability to estimate ocean harvest rates for winter-run chinook salmon.

**Coded-Wire Tagging Program.** DFG recommended that a recovery program for CWT winter-run chinook salmon should focus on the upper Sacramento River between Keswick Dam and RBDD, and Battle Creek. Tagging of winter-run chinook salmon at Coleman National Fish Hatchery has been conducted in recent years. Currently, efforts to recover tagged winter-run chinook adults have been made at California ports, Battle Creek, and Coleman National Fish Hatchery. No program for capturing, marking, and releasing naturally produced winter-run chinook salmon currently exists.

### **Spring-Run Chinook Salmon**

**Spawning Escapement.** High-priority streams for monitoring spring-run chinook salmon adult populations are the upper Sacramento River between Keswick Dam and Hamilton City, Battle Creek, Antelope Creek, Big Chico Creek, Butte Creek, Deer Creek, Mill Creek, Feather River, and Yuba River. Feather River Hatchery was also assigned a high priority for estimating adult returns. Ladder counts of spring-run chinook salmon at RBDD and hatchery counts at Feather River Hatchery since the late 1960s have provided the only long-term records of spring-run chinook adult populations in the Sacramento basin. Estimates of in-river spawning escapement based on carcass surveys or aerial redd counts in the Sacramento, Feather, and Yuba rivers have been hindered by mixing of fall- and spring-run chinook on the spawning grounds. Except for Butte Creek, records of spring-run adults returning to the smaller Sacramento River tributaries are generally incomplete. In recent years, annual escapement monitoring programs involving ladder counts and carcass surveys, and snorkel surveys have been initiated on Battle, Antelope, Big Chico, Deer, and Mill creeks.

**Inland Sport Harvest** High-priority streams identified by DFG for estimating inland sport harvest of spring-run chinook salmon are the Sacramento River between Keswick Dam and RBDD, Feather River, and Yuba River. The comments made above about inland harvest estimates of fall-run chinook salmon generally apply to spring-run chinook salmon.

**Ocean Commercial and Sport Harvest.** Because of an inability to discriminate individual races or stocks of salmon in ocean catches, estimates of the contribution of spring-run chinook salmon to the ocean commercial and sport fisheries have not been possible.

**Coded-Wire Tagging Program.** Streams and hatcheries recommended by DFG for recovery of CWT spring-run chinook salmon generally correspond to those identified as high priority for estimating spawning escapement. CWT spring-run chinook salmon produced at Feather River Hatchery are recovered at Feather River Hatchery and during carcass surveys in the Feather River and occasionally in the Yuba River. Currently, the only intensive effort to recover CWT spring-run chinook salmon occurs at Feather River Hatchery.

### **Steelhead Trout**

**Spawning Escapement.** High-priority streams recommended by DFG for monitoring steelhead spawning populations are the upper Sacramento River between Keswick Dam and Hamilton City, Battle Creek, Deer Creek, Mill Creek, and Stanislaus River. Feather River, Nimbus, and Coleman National Fish hatcheries received a medium-priority ranking. Ladder counts of steelhead adults at RBDD and hatchery counts at each hatchery listed above provide the only long-term records of adult returns. Overall, previous estimates of naturally spawning steelhead trout populations other than at RBDD are few and probably inaccurate.

**Inland Sport Harvest.** High-priority streams identified by DFG for estimating inland sport harvest of steelhead trout are the Sacramento River between Keswick Dam and Hamilton City, Battle Creek, and the American River. Sampling of inland sport catches of steelhead trout has been sporadic, short term, and geographically limited. Past steelhead harvest estimates for the Sacramento River above RBDD were developed from a regression between ladder counts and limited angler harvest data. Recently, steelhead harvest estimates were generated from year-round angler surveys conducted in the Sacramento, Feather, Yuba, and American rivers from January 1991 through December 1994.

**Ocean Commercial and Sport Harvest.** No ocean commercial or sport fishery exists for steelhead trout, nor are steelhead caught in sufficient numbers to warrant a monitoring program.

**Coded-Wire Tagging Program.** Streams and hatcheries recommended by DFG for recovery of CWT steelhead trout generally correspond to those identified above under "Spawning Escapement" and "Inland Sport Harvest". A major CWT program for hatchery steelhead does not currently exist.

### **Existing and Proposed Data Management Practices**

As expected, data management practices, where they could be determined, varied between monitoring programs. Larger programs typically entered collected data into a computerized database, however, which makes such data available to other programs, such as CAMP.

The Service and other agencies have committed to provide a central data repository or "warehouse" within IEP. The IEP comprises state and federal resource agencies conducting studies within San Francisco Bay, the Sacramento-San Joaquin Delta, and rivers and tributaries in the Central Valley. The CAMP Project Team is currently working with IEP to structure and coordinate database management in a coordinated and integrated fashion. Chapter 6 fully addresses a concept data management and data access program for CAMP and how it will be integrated with IEP's efforts.

### **CVPIA Action-Specific Monitoring Programs**

Essential to CAMP is the need for short-term, site-specific, and action-specific effectiveness monitoring as an integral part of each Section 3406(b) restoration project or action. Information from these short-term, site-specific assessments will be needed to supplement and feed into the long-term and more general CAMP.

Currently, no site- or action-specific monitoring programs are designed or implemented. Such information is critically important for CAMP, but will need to be included in CAMP as they are designed and implemented. For purposes of developing this Conceptual Plan for CAMP, it has been assumed that each 3406(b) action will have a short-term monitoring program that is sufficiently funded, designed, and conducted to determine whether each measure was effective.

Table B-3. Anadromous Fish Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
American River	Lower American River Chinook Salmon Escapement Survey	Spawning adult	Carcass survey	Fall-run chinook	DFG	42	1954	Ongoing
	Lower American River Chinook Salmon and Steelhead Trout Redd Survey	Spawning adult	Redd survey	Fall-run chinook	DFG	4	1991	Completed
	Nimbus Salmon and Steelhead Hatchery	Spawning adult	Hatchery counts	Fall-run chinook	DFG	41	1955	Ongoing
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	Fall-run chinook	DFG	4	1990	Completed
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	Steelhead	DFG	4	1990	Completed
	Nimbus Salmon and Steelhead Hatchery	Spawning adult	Hatchery counts	Steelhead	DFG	41	1955	Ongoing
	Lower American River Chinook Salmon and Steelhead Trout Redd Survey	Spawning adult	Redd survey	Steelhead	DFG	4	1991	Completed
	Lower American River Emigration Survey	Emigrating fry	Screw trapping	Fall-run chinook	DFG	4	1992	Ongoing
	Nimbus Salmon and Steelhead Hatchery	Incubating eggs	Hatchery counts	Fall-run chinook	DFG	41	1955	Ongoing
	Nimbus Salmon and Steelhead Hatchery	Rearing juvenile	Hatchery counts	Fall-run chinook	DFG	41	1955	Ongoing
	Lower American River Fish Community Survey	Rearing juvenile	Beach seining	Fall-run chinook	DFG	3	1992	Completed
	Lower American River Emigration Survey	Emigrating juvenile	Screw trapping	Fall-run chinook	DFG	4	1992	Ongoing
	Lower American River Fish Community Survey	Rearing fry	Beach seining	Fall-run chinook	DFG	3	1992	Completed
	Nimbus Salmon and Steelhead Hatchery	Rearing juvenile	Hatchery counts	Steelhead	DFG	41	1955	Ongoing
	Nimbus Salmon and Steelhead Hatchery	Incubating eggs	Hatchery counts	Steelhead	DFG	41	1955	Ongoing
	Lower American River Emigration Survey	Larvae	Screw trapping	American shad	DFG	4	1992	Ongoing
	Lower American River Fish Community Survey	Rearing juvenile	Beach seining	Steelhead	DFG	3	1992	Completed
	Lower American River Emigration Survey	Emigrating juvenile	Screw trapping	Steelhead	DFG	4	1992	Ongoing
	Lower American River Fish Community Survey	Rearing fry	Beach seining	Steelhead	DFG	3	1992	Completed
Battle Creek	Battle Creek Studies	Spawning adult	Aerial survey	Fall-run chinook	DFG	2	1989	Completed
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Fall-run chinook	DFG	2	1993	Ongoing
	Battle Creek Studies	Spawning adult	Carcass survey	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Incubating eggs	Carcass survey	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Spawning adult	Ladder counts	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Incubating eggs	Ladder counts	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Spawning adult	Snorkel survey	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Incubating eggs	Snorkel survey	Fall-run chinook	DFG	2	1989	Completed
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Spring-run chinook	DFG	2	1993	Ongoing
	Battle Creek Studies	Spawning adult	Aerial survey	Spring-run chinook	DFG	2	1989	Completed
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Spring-run chinook	DFG	2	1993	Ongoing
	Battle Creek Studies	Spawning adult	Carcass survey	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Incubating eggs	Carcass survey	Spring-run chinook	DFG	2	1989	Completed
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Spring-run chinook	USFWS	2	1995	Ongoing
	Battle Creek Studies	Spawning adult	Ladder counts	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Incubating eggs	Ladder counts	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Spawning adult	Snorkel survey	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Incubating eggs	Snorkel survey	Spring-run chinook	DFG	2	1989	Completed
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Winter-run chinook	USFWS	2	1993	On-going
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Winter-run chinook	USFWS	2	1995	On-going
	Battle Creek Studies	Spawning adult	Aerial survey	Steelhead	DFG	2	1989	Completed
	Battle Creek Studies	Spawning adult	Carcass survey	Steelhead	DFG	2	1989	Completed
	Battle Creek Studies	Incubating eggs	Carcass survey	Steelhead	DFG	2	1989	Completed
	Battle Creek Studies	Spawning adult	Ladder counts	Steelhead	DFG	2	1989	Completed

Table B-3. Continued

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
Battle Creek Studies		Incubating eggs	Ladder counts	Steelhead	DFG	2	1989	Completed
Battle Creek Studies		Spawning adult	Snorkel survey	Steelhead	DFG	2	1989	Completed
Battle Creek Studies		Incubating eggs	Snorkel survey	Steelhead	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Spawning adult	Other	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Adult	Other	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies (spawning gravel analysis)		Spawning adult	Other	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies (spawning gravel analysis)		Incubating eggs	Other	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies (water temperature modeling)		Spawning adult	Other	Fall-run chinook	DFG	2	1989	Ongoing
Battle Creek Studies (water temperature modeling)		Incubating eggs	Other	Fall-run chinook	DFG	2	1989	Ongoing
Battle Creek Studies (barrier survey)		Spawning adult	Other	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies (barrier survey)		Incubating eggs	Other	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Rearing fry	Other	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Rearing juvenile	Other	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies (water temperature modeling)		Rearing fry	Other	Fall-run chinook	DFG	2	1989	Ongoing
Battle Creek Studies (water temperature modeling)		Rearing juvenile	Other	Fall-run chinook	DFG	2	1989	Ongoing
Battle Creek Studies (barrier survey)		Rearing fry	Other	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies (barrier survey)		Rearing juvenile	Other	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Spawning adult	Other	Spring-run chinook	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Adult	Other	Spring-run chinook	DFG	2	1989	Completed
Battle Creek Studies (spawning gravel analysis)		Spawning adult	Other	Spring-run chinook	DFG	2	1989	Completed
Battle Creek Studies (spawning gravel analysis)		Incubating eggs	Other	Spring-run chinook	DFG	2	1989	Completed
Battle Creek Studies (water temperature modeling)		Spawning adult	Other	Spring-run chinook	DFG	2	1989	Ongoing
Battle Creek Studies (water temperature modeling)		Incubating eggs	Other	Spring-run chinook	DFG	2	1989	Ongoing
Battle Creek Studies (barrier survey)		Spawning adult	Other	Spring-run chinook	DFG	2	1989	Completed
Battle Creek Studies (barrier survey)		Incubating eggs	Other	Spring-run chinook	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Rearing fry	Other	Spring-run chinook	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Rearing juvenile	Other	Spring-run chinook	DFG	2	1989	Completed
Battle Creek Studies (water temperature modeling)		Rearing fry	Other	Spring-run chinook	DFG	2	1989	Ongoing
Battle Creek Studies (water temperature modeling)		Rearing juvenile	Other	Spring-run chinook	DFG	2	1989	Ongoing
Battle Creek Studies (barrier survey)		Rearing fry	Other	Spring-run chinook	DFG	2	1989	Completed
Battle Creek Studies (barrier survey)		Rearing juvenile	Other	Spring-run chinook	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Spawning adult	Other	Steelhead	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Adult	Other	Steelhead	DFG	2	1989	Completed
Battle Creek Studies (spawning gravel analysis)		Spawning adult	Other	Steelhead	DFG	2	1989	Completed
Battle Creek Studies (spawning gravel analysis)		Incubating eggs	Other	Steelhead	DFG	2	1989	Completed
Battle Creek Studies (water temperature modeling)		Spawning adult	Other	Steelhead	DFG	2	1989	Ongoing
Battle Creek Studies (water temperature modeling)		Incubating eggs	Other	Steelhead	DFG	2	1989	Ongoing
Battle Creek Studies (barrier survey)		Spawning adult	Other	Steelhead	DFG	2	1989	Completed
Battle Creek Studies (barrier survey)		Incubating eggs	Other	Steelhead	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Rearing fry	Other	Steelhead	DFG	2	1989	Completed
Battle Creek Studies (habitat analysis)		Rearing juvenile	Other	Steelhead	DFG	2	1989	Completed
Battle Creek Studies (water temperature modeling)		Rearing fry	Other	Steelhead	DFG	2	1989	Ongoing
Battle Creek Studies (water temperature modeling)		Rearing juvenile	Other	Steelhead	DFG	2	1989	Ongoing
Battle Creek Studies (barrier survey)		Rearing fry	Other	Steelhead	DFG	2	1989	Completed
Battle Creek Studies (barrier survey)		Rearing juvenile	Other	Steelhead	DFG	2	1989	Completed
Battle Creek Studies		Rearing fry	Beach seining	Fall-run chinook	DFG	2	1989	Completed
Battle Creek Studies		Rearing juvenile	Beach seining	Fall-run chinook	DFG	2	1989	Completed

Table B-3. Continued

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
	Battle Creek Studies	Rearing fry	Electrofishing	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Rearing juvenile	Electrofishing	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies (hatchery interactions)	Rearing fry	Other	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies (hatchery interactions)	Rearing juvenile	Other	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Rearing fry	Snorkel survey	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Rearing juvenile	Snorkel survey	Fall-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Rearing fry	Beach seining	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Rearing juvenile	Beach seining	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Rearing fry	Electrofishing	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Rearing juvenile	Electrofishing	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies (hatchery interactions)	Rearing fry	Other	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies (hatchery interactions)	Rearing juvenile	Other	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Rearing fry	Snorkel survey	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Rearing juvenile	Snorkel survey	Spring-run chinook	DFG	2	1989	Completed
	Battle Creek Studies	Rearing fry	Beach seining	Steelhead	DFG	2	1989	Completed
	Battle Creek Studies	Rearing juvenile	Beach seining	Steelhead	DFG	2	1989	Completed
	Battle Creek Studies	Rearing fry	Electrofishing	Steelhead	DFG	2	1989	Completed
	Battle Creek Studies	Rearing juvenile	Electrofishing	Steelhead	DFG	2	1989	Completed
	Battle Creek Studies (hatchery interactions)	Rearing fry	Other	Steelhead	DFG	2	1989	Completed
	Battle Creek Studies (hatchery interactions)	Rearing juvenile	Other	Steelhead	DFG	2	1989	Completed
	Battle Creek Studies	Rearing fry	Snorkel survey	Steelhead	DFG	2	1989	Completed
	Battle Creek Studies	Rearing juvenile	Snorkel survey	Steelhead	DFG	2	1989	Completed
Big Chico Creek	Big Chico Adult Migration Studies	Adult	Aerial survey	Fall-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Adult Migration Studies	Adult	Snorkel survey	Fall-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Adult Migration Studies	Adult	Aerial survey	Spring-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Adult Migration Studies	Adult	Snorkel survey	Spring-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Juvenile Migration Studies	Rearing juvenile	Beach seining	Fall-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Juvenile Migration Studies	Emigrating juvenile	Beach seining	Fall-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Juvenile Migration Studies	Rearing juvenile	Fyke netting	Fall-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Juvenile Migration Studies	Emigrating juvenile	Fyke netting	Fall-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Juvenile Migration Studies	Rearing juvenile	Beach seining	Spring-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Juvenile Migration Studies	Emigrating juvenile	Beach seining	Spring-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Juvenile Migration Studies	Rearing juvenile	Fyke netting	Spring-run chinook	DFG	N/D	N/D	Ongoing
	Big Chico Juvenile Migration Studies	Emigrating juvenile	Fyke netting	Spring-run chinook	DFG	N/D	N/D	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Fall-run chinook	DFG	2	1993	Ongoing
	Butte Creek Adult Migration Studies	Adult	Aerial survey	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Fall-run chinook	DFG	2	1993	Ongoing
Butte Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Fall-run chinook	DFG	2	1993	Ongoing
	Butte Creek Adult Migration Studies	Adult	Snorkel survey	Fall-run chinook	DFG	2	1993	Ongoing
	Butte Creek: De Sabla Centerville Project	Adult	Direct observation	Fall-run chinook	PGE	13	1981	Completed
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Spring-run chinook	DFG	2	1993	Ongoing
	Butte Creek Adult Migration Studies	Adult	Aerial survey	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Spring-run chinook	DFG	2	1993	Ongoing

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Delta

Table B-3. Continued

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
	Fry and Smolt Abundance Studies	Emigrating juvenile	Screw trapping	Fall-run chinook	USFWS	N/D	N/D	Planned
	Fry and Smolt Abundance Studies	Rearing fry	Trawling	Fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Rearing juvenile	Trawling	Fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Emigrating juvenile	Trawling	Fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Rearing fry	Trawling	Fall-run chinook	USFWS	19	1976	Ongoing
	Fry and Smolt Abundance Studies	Rearing juvenile	Trawling	Fall-run chinook	USFWS	19	1976	Ongoing
	Fry and Smolt Abundance Studies	Emigrating juvenile	Trawling	Fall-run chinook	USFWS	19	1976	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Beach seining	Fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing juvenile	Screw trapping	Fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Screw trapping	Fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Beach seining	Fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Screw trapping	Fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing juvenile	Beach seining	Fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	CWT tagging	Fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Fyke netting	Fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Trawling	Fall-run chinook	DFG	5	1991	Ongoing
	Fry and Smolt Abundance Studies	Rearing fry	Beach seining	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Rearing juvenile	Beach seining	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Emigrating juvenile	Beach seining	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Rearing fry	Fyke netting	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Rearing juvenile	Fyke netting	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Emigrating juvenile	Fyke netting	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Rearing fry	Screw trapping	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Rearing juvenile	Screw trapping	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Emigrating juvenile	Screw trapping	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Rearing fry	Trawling	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Rearing juvenile	Trawling	Late fall-run chinook	USFWS	17	1978	Ongoing
	Fry and Smolt Abundance Studies	Emigrating juvenile	Trawling	Late fall-run chinook	USFWS	17	1978	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Beach seining	Late fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing juvenile	Screw trapping	Late fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Screw trapping	Late fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Beach seining	Late fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Screw trapping	Late fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing juvenile	Beach seining	Late fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	CWT tagging	Late fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Fyke netting	Late fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Trawling	Late fall-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Beach seining	Spring-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing juvenile	Screw trapping	Spring-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Screw trapping	Spring-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Beach seining	Spring-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Screw trapping	Spring-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing juvenile	Beach seining	Spring-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	CWT tagging	Spring-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Fyke netting	Spring-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Trawling	Spring-run chinook	DFG	5	1991	Ongoing

Table B-3. Continued

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
Feather River	Distribution and Abundance of Juvenile Salmonids in the Lower Sacramento River and Delta	Rearing juvenile	Beach seining	Winter-run chinook	USFWS	4	1991	Ongoing
	Distribution and Abundance of Juvenile Salmonids in the Lower Sacramento River and Delta	Emigrating juvenile	Beach seining	Winter-run chinook	USFWS	4	1991	Ongoing
	Distribution and Abundance of Juvenile Salmonids in the Lower Sacramento River and Delta	Rearing juvenile	Fyke netting	Winter-run chinook	USFWS	4	1991	Ongoing
	Distribution and Abundance of Juvenile Salmonids in the Lower Sacramento River and Delta	Emigrating juvenile	Fyke netting	Winter-run chinook	USFWS	4	1991	Ongoing
	Distribution and Abundance of Juvenile Salmonids in the Lower Sacramento River and Delta	Rearing juvenile	Screw trapping	Winter-run chinook	USFWS	4	1991	Ongoing
	Distribution and Abundance of Juvenile Salmonids in the Lower Sacramento River and Delta	Emigrating juvenile	Screw trapping	Winter-run chinook	USFWS	4	1991	Ongoing
	Distribution and Abundance of Juvenile Salmonids in the Lower Sacramento River and Delta	Rearing juvenile	Trawling	Winter-run chinook	USFWS	4	1991	Ongoing
	Distribution and Abundance of Juvenile Salmonids in the Lower Sacramento River and Delta	Emigrating juvenile	Trawling	Winter-run chinook	USFWS	4	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Beach seining	Winter-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing juvenile	Screw trapping	Winter-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Screw trapping	Winter-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Beach seining	Winter-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Screw trapping	Winter-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing juvenile	Beach seining	Winter-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	CWT tagging	Winter-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Fyke netting	Winter-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Trawling	Winter-run chinook	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Resident Fish Survey	Rearing juvenile	Electrofishing	Green sturgeon	DFG	1	1995	Ongoing
	Estuarine Monitoring Program: Sturgeon Study	Rearing juvenile	Electrofishing	White sturgeon	DFG	N/D	N/D	Ongoing
	Estuarine Monitoring Program: San Francisco Bay Monitoring	Rearing juvenile	Trawling	Green sturgeon	DFG	16	1980	Ongoing
	Estuarine Monitoring Program: Sturgeon Study	Rearing juvenile	Electrofishing	Green sturgeon	DFG	N/D	N/D	Ongoing
	Estuarine Monitoring Program: Resident Fish Survey	Rearing juvenile	Electrofishing	Striped bass	DFG	1	1995	Ongoing
	Estuarine Monitoring Program: San Francisco Bay Monitoring	Rearing juvenile	Trawling	White sturgeon	DFG	16	1980	Ongoing
	Estuarine Monitoring Program: Resident Fish Survey	Rearing juvenile	Electrofishing	White sturgeon	DFG	1	1995	Ongoing
	Estuarine Monitoring Program: San Francisco Bay Monitoring	Rearing juvenile	Trawling	Striped bass	DFG	16	1980	Ongoing
	Estuarine Monitoring Program: Midwater Trawl Survey	Rearing juvenile	Trawling	American shad	DFG	29	1967	Ongoing
	Estuarine Monitoring Program: Midwater Trawl Survey	Rearing fry	Trawling	Striped bass	DFG	29	1967	Ongoing
	Estuarine Monitoring Program: Midwater Trawl Survey	Rearing juvenile	Trawling	Striped bass	DFG	29	1967	Ongoing
	Estuarine Monitoring Program: Summer Townet Survey	Rearing fry	Townetting	Striped bass	DFG	36	1959	Ongoing
	Estuarine Monitoring Program: Summer Townet Survey	Rearing juvenile	Townetting	Striped bass	DFG	36	1959	Ongoing
	Feather River Hatchery and Thermalito Annex	Spawning adult	Hatchery counts	Fall-run chinook	DFG	29	1967	Ongoing
	Feather River Study	Spawning adult	Aerial survey	Fall-run chinook	DWR	4	1996	Planned
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	Fall-run chinook	DFG	4	1990	Completed
	Feather River Escapement Survey	Spawning adult	Carcass survey	Fall-run chinook	DFG	16	1979	Ongoing
	Feather River Escapement Survey	Spawning adult	Carcass survey	Fall-run chinook	DFG	16	1979	Ongoing
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Spawning adult	Carcass survey	Fall-run chinook	DFG	8	1967	Completed
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Incubating eggs	Other	Fall-run chinook	DFG	8	1967	Completed
	Feather River Study	Spawning adult	Aerial survey	Spring-run chinook	DWR	4	1996	Planned
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	Spring-run chinook	DFG	4	1990	Completed

Table B-3. Continued

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
	Feather River Hatchery and Thermalito Annex	Spawning adult	Hatchery counts	Spring-run chinook	DFG	29	1967	Ongoing
	Feather River Escapement Survey	Spawning adult	Carcass survey	Spring-run chinook	DFG	16	1979	Ongoing
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Spawning adult	Carcass survey	Spring-run chinook	DFG	8	1967	Completed
	Feather River Study	Spawning adult	Aerial survey	Steelhead	DWR	4	1996	Planned
	Feather River Hatchery and Thermalito Annex	Spawning adult	Hatchery	Steelhead	DFG	29	1967	Ongoing
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	Steelhead	DFG	4	1990	Completed
	Feather River Study	Spawning adult	Aerial survey	American shad	DWR	4	1996	Planned
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Immigrating adult	Creel survey	Steelhead	DFG	8	1967	Completed
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Immigrating adult	Creel survey	American shad	DFG	8	1967	Completed
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Immigrating adult	Creel survey	Striped bass	DFG	8	1967	Completed
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Incubating eggs	Survey	Fall-run chinook	DFG	8	1967	Completed
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Incubating eggs	Water Quality	Fall-run chinook	DFG	8	1967	Completed
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Incubating eggs	Temperature	American shad	DFG	8	1967	Completed
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Incubating eggs	Temperature	Striped bass	DFG	8	1967	Completed
	Feather River Hatchery and Thermalito Annex	Incubating eggs	Hatchery counts	Fall-run chinook	DFG	29	1967	Ongoing
	Feather River Outmigration Study	Emigrating juvenile	Screw trapping	Fall-run chinook	DFG	1	1995	Ongoing
	Feather River Hatchery and Thermalito Annex	Rearing juvenile	Hatchery counts	Fall-run chinook	DFG	29	1967	Ongoing
	Feather River Study	Emigrating juvenile	Screw trapping	Fall-run chinook	DWR	4	1996	Planned
	Feather River Hatchery and Thermalito Annex	Incubating eggs	Hatchery counts	Spring-run chinook	DFG	29	1967	Ongoing
	Feather River Hatchery and Thermalito Annex	Rearing juvenile	Hatchery counts	Spring-run chinook	DFG	29	1967	Ongoing
	Feather River Study	Emigrating juvenile	Screw trapping	Spring-run chinook	DWR	4	1996	Planned
	Feather River Hatchery and Thermalito Annex	Incubating eggs	Hatchery counts	Steelhead	DFG	29	1967	Ongoing
	Feather River Hatchery and Thermalito Annex	Rearing juvenile	Hatchery counts	Steelhead	DFG	29	1967	Ongoing
	Feather River Study	Emigrating juvenile	Screw trapping	Steelhead	DWR	4	1996	Planned
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Incubating eggs	Other	American shad	DFG	8	1967	Completed
	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Incubating eggs	Other	Striped bass	DFG	8	1967	Completed
Merced River	Merced River Studies	Immigrating adult	Other	Fall-run chinook	DFG/ID	N/D	N/D	Ongoing
	Merced River Studies	Spawning adult	Other	Fall-run chinook	DFG/ID	N/D	N/D	Ongoing
	Merced River Studies	Incubating eggs	Other	Fall-run chinook	DFG/ID	N/D	N/D	Ongoing
	Merced River Studies	Larvae	Other	Fall-run chinook	DFG/ID	N/D	N/D	Ongoing
	Merced River Studies	Rearing juvenile	Screw trapping	Fall-run chinook	DFG/ID	N/D	N/D	Ongoing
	Merced River Studies	Rearing juvenile	Screw trapping	Fall-run chinook	DFG/ID	N/D	N/D	Ongoing
	Merced River Studies	Emigrating juvenile	Screw trapping	Fall-run chinook	DFG/ID	N/D	N/D	Ongoing
Mill Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Rearing juvenile	Beach seining	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Beach seining	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Rearing juvenile	Electrofishing	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Electrofishing	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Rearing juvenile	Screw trapping	Fall-run chinook	DFG	2	1993	Ongoing

Table B-3. Continued

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
Mokelumne River	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Screw trapping	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Rearing juvenile	Beach seining	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Beach seining	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Rearing juvenile	Electrofishing	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Electrofishing	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Rearing juvenile	Screw trapping	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Screw trapping	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Rearing juvenile	Beach seining	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Beach seining	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Rearing juvenile	Electrofishing	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Electrofishing	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Rearing juvenile	Screw trapping	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Screw trapping	Spring-run chinook	DFG	2	1993	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 7)	Adult	Other	Fall-run chinook	Others	4	1990	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 10)	Spawning adult	Other	Fall-run chinook	Others	1	1995	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 1)	Adult	Other	Fall-run chinook	Others	4	1992	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 1)	Adult	Other	Steelhead	Others	4	1992	Ongoing
	EBMUD Salmonid Redd Surveys	Spawning adult	Redd survey	Fall-run chinook	EBMUD	6	1990	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 9)	Adult	Other	Striped bass	Others	1	1995	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 9)	Adult	Tagging	Striped bass	Others	1	1995	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 8)	Spawning adult	Other	Fall-run chinook	Others	1	1995	Ongoing
	Gravel Substrate-Streambed Profiles	Spawning adult	surveys	Fall-run chinook	Others	1	1994	Completed
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 8)	Spawning adult	Other	Steelhead	Others	1	1995	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 6)	Emigrating juvenile	Natural production/ CWTtagging	Fall-run chinook	Others	4	1991	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 6)	Emigrating juvenile	Natural production/ CWT tagging	Fall-run chinook	Others	4	1972	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 6)	Emigrating juvenile	Trawling	Fall-run chinook	Others	4	1992	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 3)	Rearing fry	Beach seining	Fall-run chinook	Others	2	1994	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 3)	Rearing juvenile	Beach seining	Fall-run chinook	Others	2	1994	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 3)	Emigrating juvenile	Beach seining	Fall-run chinook	Others	2	1994	Ongoing
	EBMUD Salmonid Rearing Abundance Surveys	Rearing fry	Beach seining	Fall-run chinook	EBMUD	5	1990	Completed
	EBMUD Salmonid Rearing Abundance Surveys	Rearing juvenile	Beach seining	Fall-run chinook	EBMUD	5	1990	Completed
	EBMUD Salmonid Rearing Abundance Surveys	Emigrating juvenile	Beach seining	Fall-run chinook	EBMUD	5	1990	Completed
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 2)	Rearing juvenile	CWT tagging	Fall-run chinook	Others	N/D	N/D	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 2)	Emigrating juvenile	CWT tagging	Fall-run chinook	Others	N/D	N/D	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 4)	Rearing juvenile	Other	Fall-run chinook	Others	1	1995	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 4)	Emigrating juvenile	Other	Fall-run chinook	Others	1	1995	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 4)	Rearing fry	Other	Fall-run chinook	Others	3	1993	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 4)	Rearing juvenile	Other	Fall-run chinook	Others	3	1993	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 4)	Emigrating juvenile	Other	Fall-run chinook	Others	3	1993	Ongoing
	EBMUD Salmonid Rearing Abundance Surveys	Rearing fry	Other	Fall-run chinook	EBMUD	5	1990	Completed
	EBMUD Salmonid Rearing Abundance Surveys	Rearing juvenile	Other	Fall-run chinook	EBMUD	5	1990	Completed
	EBMUD Salmonid Rearing Abundance Surveys	Emigrating juvenile	Other	Fall-run chinook	EBMUD	5	1990	Completed
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 3)	Rearing fry	Screw trapping	Fall-run chinook	Others	3	1993	Ongoing

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 3)	Rearing juvenile	Screw trapping	Fall-run chinook	Others	3	1993	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 3)	Emigrating juvenile	Screw trapping	Fall-run chinook	Others	3	1993	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 2)	Rearing juvenile	Screw trapping	Fall-run chinook	Others	2	1993	Completed
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 2)	Emigrating juvenile	Screw trapping	Fall-run chinook	Others	2	1993	Completed
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 5)	Rearing juvenile	Telemetry	Fall-run chinook	Others	2	1994	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 5)	Emigrating juvenile	Telemetry	Fall-run chinook	Others	2	1994	Ongoing
	EBMUD Salmonid Rearing Abundance Surveys	Rearing fry	Beach seining	Steelhead	EBMUD	5	1990	Completed
	EBMUD Salmonid Rearing Abundance Surveys	Rearing juvenile	Beach seining	Steelhead	EBMUD	5	1990	Completed
	EBMUD Salmonid Rearing Abundance Surveys	Emigrating juvenile	Beach seining	Steelhead	EBMUD	5	1990	Completed
	EBMUD Salmonid Rearing Abundance Surveys	Rearing fry	Electrofishing	Steelhead	EBMUD	5	1990	Completed
	EBMUD Salmonid Rearing Abundance Surveys	Rearing juvenile	Electrofishing	Steelhead	EBMUD	5	1990	Completed
	EBMUD Salmonid Rearing Abundance Surveys	Emigrating juvenile	Electrofishing	Steelhead	EBMUD	5	1990	Completed
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 3)	Rearing fry	Screw trapping	Steelhead	Others	3	1993	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 3)	Rearing juvenile	Screw trapping	Steelhead	Others	3	1993	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 3)	Emigrating juvenile	Screw trapping	Steelhead	Others	3	1993	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 5)	Rearing juvenile	Telemetry	Steelhead	Others	2	1994	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 5)	Emigrating juvenile	Telemetry	Steelhead	Others	2	1994	Ongoing
Stanislaus River	Stanislaus River Anadromous Fish Monitoring	Spawning adult	Direct observation	Fall-run chinook	Others	1	1994	Ongoing
Tuolumne River	Tuolumne River FERC Studies	Rearing fry	Beach seining	Fall-run chinook	DFG/ID	9	1986	Ongoing
	Tuolumne River FERC Studies	Rearing juvenile	Beach seining	Fall-run chinook	DFG/ID	9	1986	Ongoing
	Tuolumne River FERC Studies	Emigrating juvenile	Beach seining	Fall-run chinook	DFG/ID	9	1986	Ongoing
	Tuolumne River FERC Studies	Rearing fry	Screw trapping	Fall-run chinook	DFG/ID	9	1986	Ongoing
	Tuolumne River FERC Studies	Rearing juvenile	Screw trapping	Fall-run chinook	DFG/ID	9	1986	Ongoing
	Tuolumne River FERC Studies	Emigrating juvenile	Screw trapping	Fall-run chinook	DFG/ID	9	1986	Ongoing
Upper Sacramento River	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Fall-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Fall-run chinook	DFG	2	1993	Ongoing
	Red Bluff River Passage Facilities Studies	Adult	Direct observation	Fall-run chinook	USBR	3	1995	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Late fall-run chinook	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Late fall-run chinook	DFG	2	1993	Intermittent
	Red Bluff River Passage Facilities Studies	Adult	Direct observation	Late fall-run chinook	USBR	3	1995	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Spring-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Spring-run chinook	DFG	2	1993	Ongoing
	Red Bluff River Passage Facilities Studies	Adult	Direct observation	Spring-run chinook	USBR	3	1995	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	Winter-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	Winter-run chinook	DFG	2	1993	Ongoing
	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	Winter-run chinook	DFG	2	1993	Ongoing
	Red Bluff River Passage Facilities Studies	Adult	Direct observation	Winter-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Studies	Adult	Direct observation	Steelhead	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Fyke netting	Fall-run chinook	USBR	3	1995	Ongoing
	Juvenile Salmonid Beach Seining Program	Rearing fry	Beach seining	Fall-run chinook	USFWS	14	1981	Ongoing
	Juvenile Salmonid Beach Seining Program	Rearing juvenile	Beach seining	Fall-run chinook	USFWS	14	1981	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing juvenile	Fyke netting	Fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Fyke netting	Fall-run chinook	USBR	3	1995	Ongoing

Table B-3. Continued

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
	Juvenile Salmonid Beach Seining Program	Emigrating juvenile	Beach seining	Fall-run chinook	USFWS	14	1981	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Fyke netting	Fall-run chinook	DFG	15	1980	Ongoing
	GCID Juvenile Migration Studies	Emigrating juvenile	Fyke netting	Fall-run chinook	DFG	15	1980	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Screw trapping	Fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing juvenile	Screw trapping	Fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Screw trapping	Fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing fry	Screw trapping	Fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing juvenile	Screw trapping	Fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Emigrating juvenile	Screw trapping	Fall-run chinook	USBR	3	1995	Ongoing
	Juvenile Passage Efficiency Program at GCID	Rearing juvenile	Screw trapping	Fall-run chinook	DFG/ID	4	1991	Ongoing
	Juvenile Passage Efficiency Program at GCID	Emigrating juvenile	Screw trapping	Fall-run chinook	DFG/ID	4	1991	Ongoing
	Glenn-Colusa Irrigation District Studies	Rearing juvenile	Screw trapping	Fall-run chinook	DFG	10	1985	Ongoing
	Glenn-Colusa Irrigation District Studies	Emigrating juvenile	Screw trapping	Fall-run chinook	DFG	10	1985	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Screw trapping	Fall-run chinook	DFG	3	1993	Ongoing
	GCID Juvenile Migration Studies	Emigrating juvenile	Screw trapping	Fall-run chinook	DFG	3	1993	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Fyke netting	Late fall-run chinook	USBR	3	1995	Ongoing
	Juvenile Salmonid Beach Seining Program	Rearing fry	Beach seining	Late fall-run chinook	USFWS	14	1981	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing juvenile	Fyke netting	Late fall-run chinook	USBR	3	1995	Ongoing
	Juvenile Salmonid Beach Seining Program	Rearing juvenile	Beach seining	Late fall-run chinook	USFWS	14	1981	Ongoing
	Juvenile Salmonid Beach Seining Program	Emigrating juvenile	Beach seining	Late fall-run chinook	USFWS	14	1981	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Fyke netting	Late fall-run chinook	USBR	3	1995	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Fyke netting	Late fall-run chinook	DFG	15	1980	Ongoing
	GCID Juvenile Migration Studies	Emigrating juvenile	Fyke netting	Late fall-run chinook	DFG	15	1980	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Screw trapping	Late fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing juvenile	Screw trapping	Late fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Screw trapping	Late fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing fry	Screw trapping	Late fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing juvenile	Screw trapping	Late fall-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Emigrating juvenile	Screw trapping	Late fall-run chinook	USBR	3	1995	Ongoing
	Juvenile Passage Efficiency Program at GCID	Rearing juvenile	Screw trapping	Late fall-run chinook	DFG/ID	4	1991	Ongoing
	Juvenile Passage Efficiency Program at GCID	Emigrating juvenile	Screw trapping	Late fall-run chinook	DFG/ID	4	1991	Ongoing
	Glenn-Colusa Irrigation District Studies	Rearing juvenile	Screw trapping	Late fall-run chinook	DFG	10	1985	Ongoing
	Glenn-Colusa Irrigation District Studies	Emigrating juvenile	Screw trapping	Late fall-run chinook	DFG	10	1985	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Screw trapping	Late fall-run chinook	DFG	3	1993	Ongoing
	GCID Juvenile Migration Studies	Emigrating juvenile	Screw trapping	Late fall-run chinook	DFG	3	1993	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Fyke netting	Spring-run chinook	USBR	3	1995	Ongoing
	Juvenile Salmonid Beach Seining Program	Rearing fry	Beach seining	Spring-run chinook	USFWS	14	1981	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing juvenile	Fyke netting	Spring-run chinook	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Fyke netting	Spring-run chinook	USBR	3	1995	Ongoing
	Juvenile Salmonid Beach Seining Program	Rearing juvenile	Beach seining	Spring-run chinook	USFWS	14	1981	Ongoing
	Juvenile Salmonid Beach Seining Program	Emigrating juvenile	Beach seining	Spring-run chinook	USFWS	14	1981	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Fyke netting	Spring-run chinook	DFG	15	1980	Ongoing
	GCID Juvenile Migration Studies	Emigrating juvenile	Fyke netting	Spring-run chinook	DFG	15	1980	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Screw trapping	Spring-run chinook	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing juvenile	Screw trapping	Spring-run chinook	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Screw trapping	Spring-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing fry	Screw trapping	Spring-run chinook	USBR	3	1995	Ongoing

Table B-3. Continued

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
	Red Bluff River Passage Facilities Program	Rearing juvenile	Screw trapping	Spring-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Emigrating juvenile	Screw trapping	Spring-run chinook	USBR	3	1995	Ongoing
	Juvenile Passage Efficiency Program at GCID	Rearing juvenile	Screw trapping	Spring-run chinook	DFG/ID	4	1991	Ongoing
	Juvenile Passage Efficiency Program at GCID	Emigrating juvenile	Screw trapping	Spring-run chinook	DFG/ID	4	1991	Ongoing
	Glenn-Colusa Irrigation District Studies	Rearing juvenile	Screw trapping	Spring-run chinook	DFG	10	1985	Ongoing
	Glenn-Colusa Irrigation District Studies	Emigrating juvenile	Screw trapping	Spring-run chinook	DFG	10	1985	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Screw trapping	Spring-run chinook	DFG	3	1993	Ongoing
	GCID Juvenile Migration Studies	Emigrating juvenile	Screw trapping	Spring-run chinook	DFG	3	1993	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Fyke netting	Winter-run chinook	USBR	3	1995	Ongoing
	Juvenile Salmonid Beach Seining Program	Rearing fry	Beach seining	Winter-run chinook	USFWS	14	1981	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing juvenile	Fyke netting	Winter-run chinook	USBR	3	1995	Ongoing
	Juvenile Salmonid Beach Seining Program	Rearing juvenile	Beach seining	Winter-run chinook	USFWS	14	1981	Ongoing
	Juvenile Salmonid Beach Seining Program	Emigrating juvenile	Beach seining	Winter-run chinook	USFWS	14	1981	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Fyke netting	Winter-run chinook	USBR	3	1995	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Fyke netting	Winter-run chinook	DFG	15	1980	Ongoing
	GCID Juvenile Migration Studies	Emigrating juvenile	Fyke netting	Winter-run chinook	DFG	15	1980	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Screw trapping	Winter-run chinook	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing juvenile	Screw trapping	Winter-run chinook	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Screw trapping	Winter-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing fry	Screw trapping	Winter-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing juvenile	Screw trapping	Winter-run chinook	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Emigrating juvenile	Screw trapping	Winter-run chinook	USBR	3	1995	Ongoing
	Juvenile Passage Efficiency Program at GCID	Rearing juvenile	Screw trapping	Winter-run chinook	DFG/ID	4	1991	Ongoing
	Juvenile Passage Efficiency Program at GCID	Emigrating juvenile	Screw trapping	Winter-run chinook	DFG/ID	4	1991	Ongoing
	Glenn-Colusa Irrigation District Studies	Rearing juvenile	Screw trapping	Winter-run chinook	DFG	10	1985	Ongoing
	Glenn-Colusa Irrigation District Studies	Emigrating juvenile	Screw trapping	Winter-run chinook	DFG	10	1985	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Screw trapping	Winter-run chinook	DFG	3	1993	Ongoing
	GCID Juvenile Migration Studies	Emigrating juvenile	Screw trapping	Winter-run chinook	DFG	3	1993	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Fyke netting	Steelhead	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing juvenile	Fyke netting	Steelhead	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Fyke netting	Steelhead	USBR	3	1995	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Fyke netting	Steelhead	DFG	15	1980	Ongoing
	GCID Juvenile Migration Studies	Emigrating juvenile	Fyke netting	Steelhead	DFG	15	1980	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Screw trapping	Steelhead	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing juvenile	Screw trapping	Steelhead	USBR	3	1995	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Screw trapping	Steelhead	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing fry	Screw trapping	Steelhead	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing juvenile	Screw trapping	Steelhead	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Emigrating juvenile	Screw trapping	Steelhead	USBR	3	1995	Ongoing
	Juvenile Passage Efficiency Program at GCID	Rearing juvenile	Screw trapping	Steelhead	DFG/ID	4	1991	Ongoing
	Juvenile Passage Efficiency Program at GCID	Emigrating juvenile	Screw trapping	Steelhead	DFG/ID	4	1991	Ongoing
	Juvenile Passage Efficiency Program at GCID	Rearing juvenile	Screw trapping	Green sturgeon	DFG/ID	4	1991	Ongoing
	Juvenile Passage Efficiency Program at GCID	Emigrating juvenile	Screw trapping	Green sturgeon	DFG/ID	4	1991	Ongoing
	Juvenile Passage Efficiency Program at GCID	Rearing juvenile	Screw trapping	White sturgeon	DFG/ID	4	1991	Ongoing
	Juvenile Passage Efficiency Program at GCID	Emigrating juvenile	Screw trapping	White sturgeon	DFG/ID	4	1991	Ongoing
	Glenn-Colusa Irrigation District Studies	Rearing juvenile	Screw trapping	Steelhead	DFG	10	1985	Ongoing
	Glenn-Colusa Irrigation District Studies	Emigrating juvenile	Screw trapping	Steelhead	DFG	10	1985	Ongoing

Table B-3. Continued

Watershed Name	Monitoring Program Name	Target Lifestages	Monitoring Program Method	Target Species	Lead Agency	Duration (Years)	Year Began	Status
Yuba River	Glenn-Colusa Irrigation District Studies	Rearing juvenile	Screw trapping	Green sturgeon	DFG	10	1985	Ongoing
	Glenn-Colusa Irrigation District Studies	Emigrating juvenile	Screw trapping	Green sturgeon	DFG	10	1985	Ongoing
	Glenn-Colusa Irrigation District Studies	Larvae	Screw trapping	Green sturgeon	DFG	10	1985	Ongoing
	Glenn-Colusa Irrigation District Studies	Rearing juvenile	Screw trapping	White Sturgeon	DFG	10	1985	Ongoing
	Glenn-Colusa Irrigation District Studies	Emigrating juvenile	Screw trapping	White Sturgeon	DFG	10	1985	Ongoing
	Glenn-Colusa Irrigation District Studies	Larvae	Screw trapping	White Sturgeon	DFG	10	1985	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Screw trapping	Steelhead	DFG	3	1993	Ongoing
	GCID Juvenile Migration Studies	Emigrating juvenile	Screw trapping	Steelhead	DFG	3	1993	Ongoing
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	Fall-run chinook	DFG	4	1990	Completed
	Yuba River Chinook Salmon Spawning Escapement Survey	Spawning adult	Carcass survey	Fall-run chinook	DFG	43	1953	Ongoing
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	Spring-run chinook	DFG	4	1990	Completed
	Yuba River Spring Run Chinook Salmon Redd Survey	Spawning adult	Snorkel survey	Spring-run chinook	DFG	14	1982	Ongoing
	Yuba River Spring Run Chinook Salmon Redd Survey	Spawning adult	Redd survey	Spring-run chinook	DFG	14	1982	On-going
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	Steelhead	DFG	4	1990	Completed
	Yuba River Fisheries Monitoring Program	Emigrating juvenile	Snorkel survey	Fall-run chinook	Others	4	1992	On-going
	Yuba River Fisheries Monitoring Program	Emigrating juvenile	Beach seining	Fall-run chinook	Others	4	1992	On-going
	Yuba River Fisheries Monitoring Program	Rearing juvenile	Beach seining	Fall-run chinook	Others	4	1992	On-going
	Yuba River Fisheries Monitoring Program	Rearing juvenile	Snorkel survey	Fall-run chinook	Others	4	1992	On-going
	Yuba River Fisheries Monitoring Program	Rearing juvenile	Snorkel survey	Steelhead	Others	4	1992	On-going
	Yuba River Fisheries Monitoring Program	Emigrating juvenile	Snorkel survey	Steelhead	Others	4	1992	On-going
	Yuba River Fisheries Monitoring Program	Emigrating juvenile	Beach seining	Steelhead	Others	4	1992	On-going
	Yuba River Fisheries Monitoring Program	Rearing juvenile	Beach seining	Steelhead	Others	4	1992	On-going
	Yuba River Fisheries Monitoring Program	Spawning adult	Snorkel survey	American shad	Others	4	1992	On-going
Ocean Harvest	Ocean Salmon Project	Adult	Direct observation	Fall-run chinook	DFG	43	1952	On-going
	Ocean Salmon Project	Adult	Direct observation	Late fall-run chinook	DFG	43	1952	On-going
	Ocean Salmon Project	Adult	Direct observation	Spring-run chinook	DFG	43	1952	On-going
	Ocean Salmon Project	Adult	Direct observation	Winter-run chinook	DFG	43	1952	On-going

Table B-4. Fall-Run Chinook Salmon Adult Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Lifestage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status	
American River	Lower American River Chinook Salmon Escapement Survey	Spawning adult	Carcass survey	DFG	42	1954	Ongoing	
	Lower American River Chinook Salmon and Steelhead Trout Redd survey	Spawning adult	Redd survey	DFG	4	1991	Completed	
	Nimbus Salmon and Steelhead Hatchery	Spawning adult	Hatchery counts	DFG	41	1955	Ongoing	
Battle Creek	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	DFG	4	1990	Completed	
	Battle Creek Studies	Spawning adult	Aerial survey	DFG	2	1989	Completed	
				DFG	2	1993	Ongoing	
			Barrier survey	DFG	2	1989	Completed	
			Carcass survey	DFG	2	1989	Completed	
				DFG	2	1993	Ongoing	
			Ladder counts	DFG	2	1989	Completed	
				DFG	2	1993	Ongoing	
			Snorkel survey	DFG	2	1989	Completed	
			Water temp modeling	DFG	2	1989	Completed	
			Habitat analysis	DFG	2	1989	Completed	
			Adult	Habitat analysis	DFG	ND	ND	ND
			Spawning adult	Spawning gravel analysis	DFG	ND	ND	ND
Big Chico Creek	Big Chico Adult Migration Studies	Adult	Aerial survey	DFG	ND	ND	Ongoing	
			Snorkel survey	DFG	ND	ND	Ongoing	
Butte Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	DFG	2	1993	Ongoing	
			Carcass survey	DFG	2	1993	Ongoing	
			Ladder counts	DFG	2	1993	Ongoing	
	Butte Creek Adult Migration Studies	Adult	Aerial survey	DFG	2	1993	Ongoing	
			Snorkel survey	DFG	2	1993	Ongoing	
			Direct observation	PG&E	13	1981	Completed	
Cosumnes River	Cosumnes River Escapement Survey	Spawning adult	Carcass survey	DFG			Intermittent	
Cow Creek	Cow Creek Studies	Adult	Direct observation	PG&E	13	1981	Completed	
Deer Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	DFG	2	1993	Ongoing	
			Carcass survey	DFG	2	1993	Ongoing	
			Ladder counts	DFG	2	1993	Ongoing	
				DFG	2	1993	Ongoing	
Delta	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	DFG	4	1990	Completed	
Feather River	Feather River Hatchery and Thermalito Annex	Spawning adult	Hatchery counts	DFG	29	1967	Ongoing	
	Feather River Study	Spawning adult	Aerial survey	DWR	4	1996	Planned	
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	DFG	4	1990	Completed	
	Feather River Escapement Survey	Spawning adult	Carcass survey	DFG	16	1979	Ongoing	
	Evaluation of Fish Pops and Fisheries in the Post-Oroville Project Feather River	Spawning adult	Carcass survey	DFG	8	1967	Completed	
	Merced River Studies	Immigrating adult	Other	DFG/MID	ND	ND	Ongoing	
Merced River		Spawning adult	Other	DFG/MID	ND	ND	Ongoing	
Mill Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	DFG	2	1993	Ongoing	
			Carcass survey	DFG	2	1993	Ongoing	
			Ladder counts	DFG	2	1993	Ongoing	
Mokelumne River	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 7)	Adult	Other	EBMUD	4	1990	Ongoing	
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 10)	Spawning adult	Other	EBMUD	1	1995	Ongoing	
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 1)	Adult	Other	EBMUD	4	1992	Ongoing	
	EBMUD Salmonid Redd surveys	Spawning adult	Redd survey	EBMUD	6	1990	Ongoing	
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 8)	Spawning adult	Other	EBMUD	1	1995	Ongoing	
	Gravel Substrate-Streambed Profiles	Spawning adult	Habitat survey	EBMUD	1	1994	Completed	

Table B-4. Continued

Watershed Name	Monitoring Program Name	Target Lifestage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Stanislaus River	Stanislaus River Anadromous Fish Monitoring	Spawning adult	Direct observation	EBMUD	1	1994	Ongoing
Upper Sacramento River	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	DFG	2	1993	Ongoing
			Carcass survey	DFG	2	1993	Ongoing
			Ladder counts	DFG	2	1993	Ongoing
	Red Bluff River Passage Facilities Studies	Adult	Direct observation	USBR	3	1995	Ongoing
Yuba River	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	DFG	4	1990	Completed
	Yuba River Chinook Salmon Spawning Escapement Survey	Spawning adult	Carcass survey	DFG	43	1953	Ongoing
Ocean Harvest	Ocean Salmon Project	Adult	Port sampling	DFG	43	1952	Ongoing

Table B-5. Fall-Run Chinook Salmon Juvenile Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status			
American River	Lower American River Emigration Survey	Emigrating fry	Screw trapping	DFG	4	1992	Ongoing			
		Emigrating juvenile	Screw trapping	DFG	4	1992	Ongoing			
	Nimbus Salmon and Steelhead Hatchery	Incubating eggs	Hatchery counts	DFG	41	1955	Ongoing			
		Rearing juvenile	Hatchery counts	DFG	41	1955	Ongoing			
	Lower American River Fish Community Survey	Rearing juvenile	Beach seining	DFG	3	1992	Completed			
Battle Creek	Battle Creek Studies	Rearing fry	Beach seining	DFG	3	1992	Completed			
		Rearing fry	Water temperature modeling	DFG	2	1989	Completed			
			Hatchery interactions	DFG	2	1989	Completed			
			Snorkel survey	DFG	2	1989	Completed			
			Electrofishing	DFG	2	1989	Completed			
			Beach seining	DFG	2	1989	Completed			
			Barrier survey	DFG	2	1989	Completed			
			Habitat analysis	DFG	2	1989	Completed			
			Beach seining	DFG	2	1989	Completed			
			Water temperature modeling	DFG	2	1989	Completed			
			Electrofishing	DFG	2	1989	Completed			
			Hatchery interactions	DFG	2	1989	Completed			
			Barrier survey	DFG	2	1989	Completed			
			Snorkel survey	DFG	2	1989	Completed			
			Habitat analysis	DFG	2	1989	Completed			
			Big Chico Creek	Juvenile Migration Studies	Rearing juvenile	Beach seining	DFG	ND	ND	Ongoing
						Fyke netting	DFG	ND	ND	Ongoing
					Emigrating juvenile	Beach seining	DFG	ND	ND	Ongoing
	Fyke netting	DFG				ND	ND	Ongoing		
Butte Creek	Central Valley Salmon and Steelhead Program	Rearing juvenile	Beach seining	DFG	2	1993	Ongoing			
		Emigrating juvenile	Beach seining	DFG	2	1993	Ongoing			
	Butte Creek Juvenile Migration Studies	Rearing juvenile	Beach seining	DFG	2	1993	Ongoing			
		Emigrating juvenile	Beach seining	DFG	2	1993	Ongoing			
	Central Valley Salmon and Steelhead Program	Rearing juvenile	Electrofishing	DFG	2	1993	Ongoing			
		Emigrating juvenile	Screw trapping	DFG	2	1993	Ongoing			
			Electrofishing	DFG	2	1993	Ongoing			
		Screw trapping	DFG	2	1993	Ongoing				
	Butte Creek Juvenile Migration Studies	Rearing juvenile	Screw trapping	DFG	2	1993	Ongoing			
		Emigrating juvenile	Screw trapping	DFG	2	1993	Ongoing			
Deer Creek		Central Valley Salmon and Steelhead Program	Rearing juvenile	Beach seining	DFG	2	1993	Ongoing		
	Electrofishing		DFG	2	1993	Ongoing				
	Screw trapping		DFG	2	1993	Ongoing				
	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Beach seining	DFG	2	1993	Ongoing			
			Electrofishing	DFG	2	1993	Ongoing			
Delta	Fry and Smolt Abundance Studies	Rearing fry	Beach seining	USFWS	17	1978	Ongoing			
			Beach seining	USFWS	19	1976	Ongoing			
			CWT tagging	USFWS	ND	ND	Planned			
			Fyke netting	USFWS	4	1991	Ongoing			

Table B-5. Continued

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Feather River Merced River Mill Creek	Central Valley Salmon and Steelhead Program	Rearing juvenile	Fyke netting	USFWS	17	1978	Ongoing
			Screw trapping	USFWS	17	1978	Ongoing
			Screw trapping	USFWS	ND	ND	Planned
			Screw trapping	USFWS	ND	ND	Planned
			Trawling	USFWS	17	1978	Ongoing
			Trawling	USFWS	19	1976	Ongoing
			Beach seining	USFWS	19	1976	Ongoing
			Beach seining	USFWS	17	1978	Ongoing
			CWT tagging	USFWS	ND	ND	Planned
			Fyke netting	USFWS	17	1978	Ongoing
			Fyke netting	USFWS	4	1991	Ongoing
			Screw trapping	USFWS	ND	ND	Planned
			Screw trapping	USFWS	ND	ND	Planned
			Screw trapping	USFWS	17	1978	Ongoing
			Trawling	USFWS	19	1976	Ongoing
		Emigrating juvenile	Trawling	USFWS	17	1978	Ongoing
			Beach seining	USFWS	19	1976	Ongoing
			Beach seining	USFWS	17	1978	Ongoing
			CWT tagging	USFWS	ND	ND	Planned
			Fyke netting	USFWS	17	1978	Ongoing
			Fyke netting	USFWS	4	1991	Ongoing
			Screw trapping	USFWS	ND	ND	Planned
			Screw trapping	USFWS	ND	ND	Planned
			Screw trapping	USFWS	17	1978	Ongoing
			Trawling	USFWS	19	1976	Ongoing
			Trawling	USFWS	17	1978	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Beach seining	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
		Rearing juvenile	Beach seining	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
		Emigrating juvenile	Beach seining	DFG	5	1991	Ongoing
			CWT tagging	DFG	5	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Emigrating juvenile	Fyke netting	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
			Trawling	DFG	5	1991	Ongoing
Feather River	Feather River Study	Emigrating juvenile	Screw trapping	DWR	4	1996	Planned
Merced River	Merced River Studies	Rearing juvenile	Screw trapping	DFG/MID	ND	ND	Ongoing
		Emigrating juvenile	Screw trapping	DFG/MID	ND	ND	Ongoing
Mill Creek	Central Valley Salmon and Steelhead Program	Rearing juvenile	Beach seining	DFG/MID	2	1993	Ongoing
			Electrofishing	DFG	2	1993	Ongoing
			Screw trapping	DFG	2	1993	Ongoing
		Emigrating juvenile	Beach seining	DFG	2	1993	Ongoing
			Electrofishing	DFG	2	1993	Ongoing

Table B-5. Continued

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Mokelumne River	Chinook Salmon and Steelhead Monitoring Program (task 6)	Rearing fry	Screw trapping	DFG	2	1993	Ongoing
			Beach seining	Others	2	1994	Ongoing
		Rearing juvenile	Beach seining	Others	2	1994	Ongoing
		Emigrating juvenile	Beach seining	Others	2	1994	Ongoing
			Natural production/CWT tagging	Others	4	1991	Ongoing
	EBMUD Salmonid Rearing Abundance Surveys	Rearing fry	Beach seining	EBMUD	5	1990	Completed
		Rearing juvenile	Beach seining	EBMUD	5	1990	Completed
		Emigrating juvenile	Beach seining	EBMUD	5	1990	Completed
	Chinook Salmon and Steelhead Monitoring Program (task 2)	Rearing juvenile	CWT tagging	EBMUD	ND	ND	Ongoing
		Emigrating juvenile	CWT tagging	EBMUD	ND	ND	Ongoing
	Chinook Salmon and Steelhead Monitoring Program (task 4)	Rearing fry	Other	EBMUD	3	1993	Ongoing
		Rearing juvenile	Other	EBMUD	3	1993	Ongoing
			Other	EBMUD	1	1995	Ongoing
		Emigrating juvenile	Other	EBMUD	3	1993	Ongoing
			Other	EBMUD	1	1995	Ongoing
	EBMUD Salmonid Rearing Abundance Surveys	Rearing fry	Other	EBMUD	5	1990	Completed
		Rearing juvenile	Other	EBMUD	5	1990	Completed
		Emigrating juvenile	Other	EBMUD	5	1990	Completed
	Chinook Salmon and Steelhead Monitoring Program (task 3)	Rearing fry	Screw trapping	EBMUD	3	1993	Ongoing
		Rearing juvenile	Screw trapping	EBMUD	3	1993	Ongoing
		Emigrating juvenile	Screw trapping	EBMUD	3	1993	Ongoing
	Chinook Salmon and Steelhead Monitoring Program (task 2)	Rearing juvenile	Screw trapping	EBMUD	2	1993	Completed
		Emigrating juvenile	Screw trapping	EBMUD	2	1993	Completed
	Chinook Salmon and Steelhead Monitoring Program (task 5)	Rearing juvenile	Telemetry	EBMUD	2	1994	Ongoing
		Emigrating juvenile	Telemetry	EBMUD	2	1994	Ongoing
Tuolumne River	FERC Studies	Rearing fry	Beach seining	DFG/Irrigation Districts	9	1986	Ongoing
		Rearing fry	Screw trapping	DFG/Irrigation Districts	9	1986	Ongoing
		Rearing juvenile	Beach seining	DFG/Irrigation Districts	9	1986	Ongoing
		Rearing juvenile	Screw trapping	DFG/Irrigation Districts	9	1986	Ongoing
		Emigrating juvenile	Beach seining	DFG/Irrigation Districts	9	1986	Ongoing
		Emigrating juvenile	Screw trapping	DFG/Irrigation Districts	9	1986	Ongoing
Upper Sacramento River	Red Bluff Research Pumping Plant Studies	Rearing fry	Fyke netting	USBR	3	1995	Ongoing
		Rearing juvenile	Fyke netting	USBR	3	1995	Ongoing
		Emigrating juvenile	Fyke netting	USBR	3	1995	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Fyke netting	DFG	15	1980	Ongoing
		Emigrating juvenile	Fyke netting	DFG	15	1980	Ongoing

Table B-5. Continued

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Yuba River	Red Bluff Research Pumping Plant Studies	Rearing fry	Screw trapping	USBR	3	1995	Ongoing
		Rearing juvenile	Screw trapping	USBR	3	1995	Ongoing
		Emigrating juvenile	Screw trapping	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing fry	Screw trapping	USBR	3	1995	Ongoing
		Rearing juvenile	Screw trapping	USBR	3	1995	Ongoing
		Emigrating juvenile	Screw trapping	USBR	3	1995	Ongoing
	Juvenile Passage Efficiency Program at GCID	Rearing juvenile	Screw trapping	DFG/GCID	4	1991	Ongoing
		Emigrating juvenile	Screw trapping	DFG/GCID	4	1991	Ongoing
	Glenn Colusa Irrigation District Studies	Rearing juvenile	Screw trapping	DFG/GCID	10	1985	Ongoing
		Emigrating juvenile	Screw trapping	DFG/GCID	10	1985	Ongoing
	GCID Juvenile Migration Studies	Rearing juvenile	Screw trapping	DFG/GCID	3	1993	Ongoing
		Emigrating juvenile	Screw trapping	DFG/GCID	3	1993	Ongoing
	Juvenile Salmonid Beach seining Program	Rearing fry	Beach seining	USFWS	14	1981	Ongoing
		Rearing juvenile	Beach seining	USFWS	14	1981	Ongoing
		Emigrating juvenile	Beach seining	USFWS	14	1981	Ongoing
	Fisheries Monitoring Program	Rearing juvenile	Beach seining	YCWA	4	1992	Ongoing
			Snorkel survey	YCWA	4	1992	Ongoing
		Emigrating juvenile	Beach seining	YCWA	4	1992	Ongoing
			Snorkel survey	YCWA	4	1992	Ongoing

Table B-6. Late Fall-Run Chinook Salmon Adult Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Lifestage	Monitoring Program Method	Lead Agency	Duration (Years)	Year Began	Status
Battle Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	DFG	2	1993	Intermittent
			Ladder counts	DFG	2	1993	Intermittent
			Aerial survey	DFG	2	1993	Intermittent
Butte Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	DFG	2	1993	Intermittent
			Carcass survey	DFG	2	1993	Intermittent
			Ladder counts	DFG	2	1993	Intermittent
Deer Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	DFG	2	1993	Intermittent
			Carcass survey	DFG	2	1993	Intermittent
			Ladder counts	DFG	2	1993	Intermittent
Delta	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	DFG	4	1990	Completed
			Aerial survey	DFG	2	1993	Intermittent
			Carcass survey	DFG	2	1993	Intermittent
Mill Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Ladder counts	DFG	2	1993	Intermittent
			Aerial survey	DFG	2	1993	Intermittent
			Carcass survey	DFG	2	1993	Intermittent
Upper mainstem Sacramento River	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	DFG	2	1993	Intermittent
			Carcass survey	DFG	2	1993	Intermittent
			Ladder counts	DFG	2	1993	Intermittent
	Red Bluff River Passage Facilities Studies	Adult	Port sampling	USBR	3	1995	Ongoing

Table B-7. Late Fall-Run Chinook Salmon Juvenile Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Butte Creek	Central Valley Salmon and Steelhead Program	Rearing juvenile	Beach seining	DFG	2	1993	Intermittent
			Electrofishing	DFG	2	1993	Intermittent
			Screw trapping	DFG	2	1993	Intermittent
		Emigrating juvenile	Beach seining	DFG	2	1993	Intermittent
			Electrofishing	DFG	2	1993	Intermittent
			Screw trapping	DFG	2	1993	Intermittent
Deer Creek	Central Valley Salmon and Steelhead Program	Rearing juvenile	Beach seining	DFG	2	1993	Intermittent
			Electrofishing	DFG	2	1993	Intermittent
			Screw trapping	DFG	2	1993	Intermittent
		Emigrating juvenile	Beach seining	DFG	2	1993	Intermittent
			Electrofishing	DFG	2	1993	Intermittent
			Screw trapping	DFG	2	1993	Intermittent
Delta	Estuarine Monitoring Program	Rearing fry	Beach seining	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
		Rearing juveniles	Beach seining	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
		Emigrating juveniles	Beach seining	DFG	5	1991	Ongoing
			CWT tagging	DFG	5	1991	Ongoing
			Fyke netting	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
			Trawling	DFG	5	1991	Ongoing
	Fry and Smolt Abundance Studies	Rearing fry	Beach seining	USFWS	17	1978	Ongoing
			Fyke netting	USFWS	17	1978	Ongoing
			Screw trapping	USFWS	17	1978	Ongoing
			Trawling	USFWS	17	1978	Ongoing
		Rearing juvenile	Beach seining	USFWS	17	1978	Ongoing
			Fyke netting	USFWS	17	1978	Ongoing
			Screw trapping	USFWS	17	1978	Ongoing
			Trawling	USFWS	17	1978	Ongoing
		Emigrating juvenile	Beach seining	USFWS	17	1978	Ongoing
			Fyke netting	USFWS	17	1978	Ongoing
Mill Creek	Central Valley Salmon and Steelhead Program	Rearing juvenile	Screw trapping	USFWS	17	1978	Ongoing
			Trawling	USFWS	17	1978	Ongoing
			Beach seining	DFG	2	1993	Intermittent
			Electrofishing	DFG	2	1993	Intermittent
	Central Valley Salmon and Steelhead Program	Emigrating juvenile	Screw trapping	DFG	2	1993	Intermittent
			Beach seining	DFG	2	1993	Intermittent
			Electrofishing	DFG	2	1993	Intermittent
			Screw trapping	DFG	2	1993	Intermittent

Table B-7. Continued

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Upper Sacramento River	GCID Juvenile Migration Studies	Rearing juvenile	Fyke netting	DFG	15	1980	Ongoing
			Screw trapping	DFG	3	1993	Ongoing
		Emigrating juvenile	Fyke netting	DFG	15	1980	Ongoing
			Screw trapping	DFG	3	1993	Ongoing
	Glenn Colusa Irrigation District Studies	Rearing juvenile	Screw trapping	DFG	10	1985	Ongoing
		Emigrating juvenile	Screw trapping	DFG	10	1985	Ongoing
	Juvenile Passage Efficiency Program at GCID	Rearing juvenile	Screw trapping	DFG	4	1991	Ongoing
		Emigrating juvenile	Screw trapping	DFG	4	1991	Ongoing
	Juvenile Salmonid Beach Seining Program	Rearing fry	Beach seining	USFWS	14	1981	Ongoing
		Rearing juvenile	Beach seining	USFWS	14	1981	Ongoing
		Emigrating juveniles	Beach seining	USFWS	14	1981	Ongoing
	Red Bluff Research Pumping Plant Studies	Rearing fry	Fyke netting	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
		Rearing juvenile	Fyke netting	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
		Emigrating juvenile	Fyke netting	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing fry	Screw trapping	USBR	3	1995	Ongoing
		Rearing juvenile	Screw trapping	USBR	3	1995	Ongoing
		Emigrating juvenile	Screw trapping	USBR	3	1995	Ongoing
	Juvenile Salmonid Beach Seining Program	Rearing fry	Beach seining	USFWS	14	1981	Ongoing
		Rearing juvenile	Beach seining	USFWS	14	1981	Ongoing
		Emigrating juvenile	Beach seining	USFWS	14	1981	Ongoing

Table B-8. Winter-Run Chinook Salmon Adult Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Battle Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	DFG	2	1993	Ongoing
			Ladder counts	DFG	2	1993	Ongoing
Delta	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	DFG	4	1990	Completed
Upper Mainstem Sacramento River	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	DFG	2	1993	Ongoing
			Carcass survey	DFG	2	1993	Ongoing
			Ladder counts	DFG	2	1993	Ongoing
			Direct observation	USBR	3	1995	Ongoing
Ocean Harvest	Red Bluff River Passage Facilities Studies	Adult	Direct observation	USBR	3	1995	Ongoing
	Ocean Salmon Project	Adult	Port sampling	DFG	43	1952	Ongoing

Table B-9. Winter-Run Chinook Salmon Juvenile Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Method	Lead Agency	Duration (Years)	Year Began	Status
Delta	Distribution and Abundance of Juvenile Salmonids in the Lower Sacramento River and Delta	Rearing juvenile	Beach seining	USFWS	4	1991	Ongoing
			Fyke netting	USFWS	4	1991	Ongoing
			Screw trapping	USFWS	4	1991	Ongoing
		Emigrating juvenile	Trawling	USFWS	4	1991	Ongoing
			Beach seining	USFWS	4	1991	Ongoing
			Fyke netting	USFWS	4	1991	Ongoing
			Screw trapping	USFWS	4	1991	Ongoing
			Trawling	USFWS	4	1991	Ongoing
	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Beach seining	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
		Rearing juvenile	Beach seining	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
		Emigrating juvenile	Beach seining	DFG	5	1991	Ongoing
			CWT tagging	DFG	5	1991	Ongoing
			Fyke netting	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
			Trawling	DFG	5	1991	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
Upper Sacramento River	Red Bluff Research Pumping Plant Studies	Rearing fry	Screw trapping	USBR	3	1995	Ongoing
		Rearing juvenile	Fyke netting	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
		Emigrating juvenile	Fyke netting	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
	Glenn Colusa Irrigation District Juvenile Migration Studies	Rearing juvenile	Fyke netting	DFG	15	1980	Ongoing
			Screw trapping	DFG	3	1993	Ongoing
		Emigrating juvenile	Fyke netting	DFG	15	1980	Ongoing
			Screw trapping	DFG	3	1993	Ongoing
	Red Bluff River Passage Facilities Program	Rearing fry	Screw trapping	USBR	3	1995	Ongoing
		Rearing juvenile	Screw trapping	USBR	3	1995	Ongoing
		Emigrating juvenile	Screw trapping	USBR	3	1995	Ongoing
	Juvenile Passage Efficiency Program at Glenn Colusa Irrigation District	Rearing juvenile	Screw trapping	DFG	4	1991	Ongoing
		Emigrating juvenile	Screw trapping	DFG	4	1991	Ongoing
		Rearing juvenile	Screw trapping	DFG	10	1985	Ongoing
	Glenn Colusa Irrigation District Studies	Emigrating juvenile	Screw trapping	DFG	10	1985	Ongoing
		Juvenile Salmonid Beach Seining Program	Rearing fry	USFWS	14	1981	Ongoing
			Rearing juvenile	USFWS	14	1981	Ongoing
			Emigrating juvenile	USFWS	14	1981	Ongoing

Table B-10. Spring-Run Chinook Salmon Adult Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Lifestage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Battle Creek	Battle Creek Studies	Incubating eggs	Barrier survey	DFG	2	1989	Completed
			Carcass survey	DFG	2	1989	Completed
			Ladder counts	DFG	2	1989	Completed
			Snorkel survey	DFG	2	1989	Completed
			Spawning gravel analysis	DFG	2	1989	Completed
			Water temperature modeling	DFG	2	1989	Completed
		Adult	Habitat analysis	DFG	2	1989	Completed
			Aerial survey	DFG	2	1989	Completed
			Barrier survey	DFG	2	1989	Completed
			Carcass survey	DFG	2	1989	Completed
			Habitat analysis	DFG	2	1989	Completed
			Ladder counts	DFG	2	1989	Completed
		Spawning adult	Snorkel survey	DFG	2	1989	Completed
			Spawning gravel analysis	DFG	2	1989	Completed
			Water temperature modeling	DFG	2	1989	Completed
	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	DFG	2	1993	Ongoing
			Carcass survey	DFG	2	1993	Ongoing
			Ladder counts	DFG	2	1993	Ongoing
Big Chico Creek	Big Chico Adult Migration Studies	Adult	Aerial survey	DFG	ND	ND	Ongoing
Butte Creek	Butte Creek Adult Migration Studies	Adult	Snorkel survey	DFG	ND	ND	Ongoing
			Aerial survey	DFG	2	1993	Ongoing
	Butte Creek: De Sabla Centerville Project Central Valley Salmon and Steelhead Program	Adult	Snorkel survey	DFG	2	1993	Ongoing
		Spawning adult	Direct observation	PGE	13	1988	Completed
			Aerial survey	DFG	2	1993	Ongoing
Cow Creek Deer Creek	Cow Creek Studies Central Valley Salmon and Steelhead Program	Adult	Carcass survey	DFG	2	1993	Ongoing
			Ladder counts	DFG	2	1993	Ongoing
			Direct observation	PGE	13	1988	Completed
		Spawning adult	Aerial survey	DFG	2	1993	Ongoing
			Carcass survey	DFG	2	1993	Ongoing
Delta Feather River	Sacramento River Sport Fish Catch Inventory Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River Escapement Survey	Immigrating adult	Ladder counts	DFG	2	1993	Ongoing
		Spawning adults	Creel survey	DFG	4	1990	Completed
			Carcass survey	DFG	8	1967	Completed
		Spawning adults	Carcass survey	DFG	16	1979	Ongoing
Mill Creek	Central Valley Salmon and Steelhead Program	Spawning adult	Carcass survey	DFG	2	1993	Ongoing
			Aerial survey	DFG	2	1993	Ongoing
			Carcass survey	DFG	2	1993	Ongoing
			Ladder counts	DFG	2	1993	Ongoing
Upper Sacramento River	Central Valley Salmon and Steelhead Program	Spawning adult	Aerial survey	DFG	2	1993	Ongoing
			Carcass survey	DFG	2	1993	Ongoing
			Ladder counts	DFG	2	1993	Ongoing
			Direct observation	USBR	3	1995	Ongoing
Yuba River	Red Bluff River Passage Facilities Studies	Adult	Creel survey	DFG	4	1990	Completed
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Redd survey	DFG	14	1982	Ongoing
	Yuba River Spring Run Chinook Salmon Redd survey	Spawning adult	Snorkel survey	DFG	14	1982	Ongoing
Ocean Harvest	Ocean Salmon Project	Adult	Direct observation	DFG	43	1952	Ongoing

Table B-11. Continued

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Mill Creek	Central Valley Salmon and Steelhead Program	Rearing juvenile	Beach seining	DFG	2	1993	Ongoing
			Electrofishing	DFG	2	1993	Ongoing
			Screw trapping	DFG	2	1993	Ongoing
		Emigrating juvenile	Beach seining	DFG	2	1993	Ongoing
			Electrofishing	DFG	2	1993	Ongoing
			Screw trapping	DFG	2	1993	Ongoing
Upper Sacramento River	Glenn Colusa Irrigation District Juvenile Migration Studies	Rearing juvenile	Fyke netting	DFG	15	1980	Ongoing
		Emigrating juvenile	Screw trapping	DFG	3	1993	Ongoing
	Fyke netting		DFG	15	1980	Ongoing	
	Screw trapping		DFG	3	1993	Ongoing	
	Glenn Colusa Irrigation District Studies	Rearing juvenile	Screw trapping	DFG	10	1985	Ongoing
		Emigrating juvenile	Screw trapping	DFG	10	1985	Ongoing
	Juvenile Passage Efficiency Program at Glenn Colusa Irrigation District	Rearing juvenile	Screw trapping	DFG	4	1991	Ongoing
	Juvenile Salmonid Beach Seining Program	Emigrating juvenile	Screw trapping	DFG	4	1991	Ongoing
		Rearing fry	Beach seining	USFWS	14	1981	Ongoing
		Rearing juvenile	Beach seining	USFWS	14	1981	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Beach seining	USFWS	14	1981	Ongoing
		Rearing fry	Fyke netting	USBR	3	1995	Ongoing
		Rearing juvenile	Screw trapping	USBR	3	1995	Ongoing
			Fyke netting	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
		Emigrating juvenile	Fyke netting	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
	Red Bluff River Passage Facilities Program	Rearing fry	Screw trapping	USBR	3	1995	Ongoing
		Rearing juvenile	Screw trapping	USBR	3	1995	Ongoing
		Emigrating juvenile	Screw trapping	USBR	3	1995	Ongoing

Table B-11. Spring-Run Chinook Salmon Juvenile Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Battle Creek	Battle Creek Studies	Rearing fry	Barrier survey	DFG	2	1989	Completed
			Beach seining	DFG	2	1989	Completed
			Electrofishing	DFG	2	1989	Completed
			Hatchery interactions	DFG	2	1989	Completed
			Snorkel survey	DFG	2	1989	Completed
			Water temperature modeling	DFG	2	1989	Completed
			Habitat analysis	DFG	2	1989	Completed
		Rearing juvenile	Barrier survey	DFG	2	1989	Completed
			Beach seining	DFG	2	1989	Completed
			Electrofishing	DFG	2	1989	Completed
			Hatchery interactions	DFG	2	1989	Completed
			Snorkel survey	DFG	2	1989	Completed
			Water temperature modeling	DFG	2	1989	Completed
			Habitat analysis	DFG	2	1989	Completed
Big Chico Creek	Big Chico Juvenile Migration Studies	Rearing juvenile	Beach seining	DFG	ND	ND	Ongoing
			Fyke netting	DFG	ND	ND	Ongoing
		Emigrating juvenile	Beach seining	DFG	ND	ND	Ongoing
			Fyke netting	DFG	ND	ND	Ongoing
Butte Creek	Butte Creek Juvenile Migration Studies	Rearing juvenile	Beach seining	DFG	2	1993	Ongoing
			Screw trapping	DFG	2	1993	Ongoing
		Emigrating juvenile	Beach seining	DFG	2	1993	Ongoing
			Screw trapping	DFG	2	1993	Ongoing
Deer Creek	Central Valley Salmon and Steelhead Program	Rearing juvenile	Beach seining	DFG	2	1993	Ongoing
			Electrofishing	DFG	2	1993	Ongoing
			Screw trapping	DFG	2	1993	Ongoing
		Emigrating juvenile	Beach seining	DFG	2	1993	Ongoing
			Electrofishing	DFG	2	1993	Ongoing
			Screw trapping	DFG	2	1993	Ongoing
Delta	Estuarine Monitoring Program: Juvenile Salmon Migration	Rearing fry	Beach seining	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
		Rearing juveniles	Beach seining	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
		Emigrating juveniles	Beach seining	DFG	5	1991	Ongoing
			CWT tagging	DFG	5	1991	Ongoing
			Fyke netting	DFG	5	1991	Ongoing
			Screw trapping	DFG	5	1991	Ongoing
			Trawling	DFG	5	1991	Ongoing
Feather River	Feather River Study	Emigrating juveniles	Screw trapping	DWR	4	1996	Planned

Table B-12. Steelhead Adult Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Method	Lead Agency	Duration (Years)	Year Began	Status
Battle Creek	Battle Creek Studies	Adult	Habitat analysis	DFG	2	1989	Completed
		Spawning adult	Barrier survey	DFG	2	1989	Completed
			Habitat analysis	DFG	2	1989	Completed
			Spawning gravel analysis	DFG	2	1989	Completed
			Water temperature modeling	DFG	2	1989	Completed
Cosumnes River	Cosumnes River Escapement Survey	Spawning adult	Carcass survey	DFG	ND	ND	Intermittent
Delta	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	DFG	4	1990	Completed
Feather River	Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Immigrating adult	Creel survey	DFG	8	1967	Completed
	Feather River Hatchery and Thermalito Annex	Spawning adult	Hatchery count	DFG	29	1967	Ongoing
	Feather River Study	Spawning adult	Aerial survey	DWR	4	1996	Planned
	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	DFG	4	1990	Completed
Mokelumne River	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 1)	Adult	Other	EBMUD	4	1992	Ongoing
	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 8)	Spawning adult	Other	EBMUD	1	1995	Ongoing
Upper Sacramento River	Red Bluff River Passage Facilities Studies	Adult	Direct observation	USBR	3	1995	Ongoing
Yuba River	Sacramento River Sport Fish Catch Inventory	Immigrating adult	Creel survey	DFG	4	1990	Completed

Table B-13. Steelhead Juvenile Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
American River	Lower American River Emigration Survey	Emigrating juvenile	Screw trapping	DFG	4	1992	Ongoing
		Rearing juvenile	Beach seining	DFG	3	1992	Completed
	Lower American River Fish Community Survey	Rearing fry	Beach seining	DFG	3	1992	Completed
		Rearing juvenile	Hatchery counts	DFG	41	1955	Ongoing
		Incubating eggs	Hatchery counts	DFG	41	1955	Ongoing
Battle Creek	Battle Creek Studies	Rearing fry	Barrier survey	DFG	2	1989	Completed
			Habitat analysis	DFG	2	1989	Completed
			Beach seining	DFG	2	1989	Completed
			Electrofishing	DFG	2	1989	Completed
			Other	DFG	2	1989	Completed
			Snorkel survey	DFG	2	1989	Completed
			Water temperature modeling	DFG	2	1989	Completed
		Rearing juvenile	Barrier survey	DFG	2	1989	Completed
			Habitat analysis	DFG	2	1989	Completed
			Beach seining	DFG	2	1989	Completed
			Electrofishing	DFG	2	1989	Completed
			Other	DFG	2	1989	Completed
			Snorkel survey	DFG	2	1989	Completed
			Water temperature modeling	DFG	2	1989	Completed
			Hatchery counts	DFG	29	1967	Ongoing
			Hatchery counts	DFG	29	1967	Ongoing
			Screw trapping	DFG	4	1996	Planned
Mokelumne River	Feather River Hatchery and Thermalito Annex	Incubating eggs	Hatchery counts	DFG	29	1967	Ongoing
		Rearing juvenile	Hatchery counts	DFG	29	1967	Ongoing
	Feather River Study	Emigrating juvenile	Screw trapping	DFG	4	1996	Planned
		Emigrating juvenile	Beach seining	EBMUD	5	1990	Completed
	EBMUD Salmonid Rearing Abundance Surveys	Rearing fry	Electrofishing	EBMUD	5	1990	Completed
			Beach seining	EBMUD	5	1990	Completed
		Rearing juvenile	Electrofishing	EBMUD	5	1990	Completed
			Beach seining	EBMUD	5	1990	Completed
		Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 3)	Electrofishing	EBMUD	5	1990	Completed
			Screw trapping	EBMUD	3	1993	Ongoing
			Telemetry	EBMUD	3	1993	Ongoing
		Rearing fry	Screw trapping	EBMUD	3	1993	Ongoing
		Rearing juvenile	Screw trapping	EBMUD	3	1993	Ongoing
			Telemetry	EBMUD	2	1994	Ongoing
Upper Sacramento River	GCID Juvenile Migration Studies	Emigrating juvenile	Screw trapping	GCID	3	1993	Ongoing
			Fyke netting	DFG	15	1980	Ongoing
		Rearing juvenile	Screw trapping	GCID	3	1993	Ongoing
			Fyke netting	DFG	15	1980	Ongoing
		Emigrating juvenile	Screw trapping	DFG&GCID	10	1985	Ongoing
		Rearing juvenile	Screw trapping	DFG&GCID	10	1985	Ongoing
	Glenn Colusa Irrigation District Studies	Emigrating juvenile	Screw trapping	DFG&GCID	4	1991	Ongoing
		Rearing juvenile	Screw trapping	DFG&GCID	4	1991	Ongoing
		Juvenile Passage Efficiency Program at GCID	Screw trapping	DFG&GCID	4	1991	Ongoing
	Red Bluff Research Pumping Plant Studies	Emigrating juvenile	Fyke netting	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
		Rearing fry	Fyke netting	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing

Table B-13. Continued

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Yuba River	Red Bluff River Passage Facilities Program	Rearing juvenile	Fyke netting	USBR	3	1995	Ongoing
			Screw trapping	USBR	3	1995	Ongoing
		Emigrating juvenile	Screw trapping	USBR	3	1995	Ongoing
	Yuba River Fisheries Monitoring Program	Rearing fry	Screw trapping	USBR	3	1995	Ongoing
		Rearing juvenile	Screw trapping	USBR	3	1995	Ongoing
		Emigrating juvenile	Snorkel survey	Other	4	1992	Ongoing
			Beach seining	Other	4	1992	Ongoing
		Rearing juvenile	Snorkel survey	Other	4	1992	Ongoing
			Beach seining	Other	4	1992	Ongoing

Table B-14. Striped Bass Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Delta	Estuarine Monitoring Program: Adult Striped Bass Population Study	Adult	Tagging	DFG	27	1969	Ongoing
			Creel survey	DFG	27	1969	Ongoing
	Estuarine Monitoring Program: Midwater Trawl Survey	Rearing fry	Trawling	DFG	29	1967	Ongoing
		Rearing juvenile	Trawling	DFG	29	1967	Ongoing
	Estuarine Monitoring Program: Resident Fish Survey	Rearing juvenile	Electrofishing	DFG	1	1995	Ongoing
	Estuarine Monitoring Program: San Francisco Bay Monitoring	Rearing juvenile	Trawling	DFG	16	1980	Ongoing
	Estuarine Monitoring Program: Summer Trawl Survey	Rearing fry	Townetting	DFG	36	1959	Ongoing
		Rearing juvenile	Townetting	DFG	36	1959	Ongoing
Feather River	An Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Immigrating adult	Creel survey	DFG	8	1967	Completed
		Incubating eggs	Other	DFG	8	1967	Completed
			Other	DFG	8	1967	Completed
			Water temperature modeling	DFG	8	1967	Completed
Mokelumne River	Mokelumne River Chinook Salmon and Steelhead Monitoring Program (task 9)	Adult	Other	EBMUD	1	1995	Ongoing
			Other	EBMUD	1	1995	Ongoing

Table B-15. American Shad Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Life Stage	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
American River	Lower American River Emigration Survey	Larvae	Screw trapping	DFG	4	1992	Ongoing
Delta	Estuarine Monitoring Program: Midwater Trawl Survey	Rearing juvenile	Trawling	DFG	29	1967	Ongoing
Feather River	An Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River	Immigrating adult	Creel survey	DFG	8	1967	Completed
		Incubating eggs	Water temperature modeling	DFG	8	1967	Completed
		Incubating eggs	Other	DFG	8	1967	Completed
Yuba River	Yuba River Fisheries Monitoring Program	Spawning adult	Snorkel survey	YCWA	4	1992	Ongoing

Table B-16. White Sturgeon and Green Sturgeon Monitoring Programs in the Central Valley

Watershed Name	Monitoring Program Name	Target Life Stages	Monitoring Program Methods	Lead Agency	Duration (Years)	Year Began	Status
Delta	Estuarine Monitoring Program: Sturgeon Study	Adult	Tagging	DFG	ND	ND	Ongoing
		Rearing juvenile	Electrofishing	DFG	ND	ND	Ongoing
Upper Mainstem Sacramento River	Estuarine Monitoring Program: San Francisco Bay Monitoring	Rearing juvenile	Trawling	DFG	16	1980	Ongoing
	Estuarine Monitoring Program: Resident Fish Survey	Rearing juvenile	Electrofishing	DFG	1	1995	Ongoing
	Juvenile Passage Efficiency Program at GCID	Rearing juvenile	Screw trapping	DFG	4	1991	Ongoing
		Emigrating juvenile	Screw trapping	DFG	4	1991	Ongoing
	Glenn Colusa Irrigation District Studies	Larvae	Screw trapping	DFG	10	1985	Ongoing
		Rearing juvenile	Screw trapping	DFG	10	1985	Ongoing
		Emigrating juvenile	Screw trapping	DFG	10	1985	Ongoing

Table B-17. USGS and DWR Stream Gaging Stations for Habitat Monitoring

Watershed Name	USGS Station ID	DWR Station ID	Latitude	Longitude	Station Name	Parameters Measured	First Year of Record	Last Year of Record	Years Operated
American River	11446500	A0-7175	383808	1211336	AMERICAN R A FAIR OAKS CA	Flow	1905	1994	90
						Stage	1974	1975	2
						Temp-H2O	1962	1979	18
Antelope Creek	11447000 11379000	A0-7140 A4-5111	383405 401214	1212520 1220702	AMERICAN R A SACRAMENTO CA ANTELOPE C NR RED BLUFF CA	Flow	1944	1959	16
						Flow	1941	1982	42
						Stage	1974	1975	2
Battle Creek	11376550	A4-7105	402354	1220843	BATTLE CR BL COLEMAN FISH HATCHERY NR COTTONW	Flow	1941	1994	53
						Stage	1974	1975	2
						Temp-H2O	1966	1979	13
Bear Creek	11374100	A4-0750	403150	1220630	BEAR C NR MILLVILLE CA	Flow	1960	1967	8
Big Chico Creek	11384000	N/A	394635	1214510	BIG CHICO C NR CHICO CA	Flow	1931	1986	56
						Stage	1974	1975	2
Butte Creek	11390000	A4-1110	394334	1214228	BUTTE C NR CHICO CA	Flow	1931	1994	64
						Stage	1974	1975	2
						Temp-H2O	1962	1979	18
Calaveras Creek	11390010 11308900	A0-4265 B2-5300	394036 380853	1214642 1204926	BUTTE C NR DURHAM CA CALAVERAS R BL NEW HOGAN DAM NR VALLEY SPRINGS C	Flow	1959	1973	15
						Flow	1945	1992	33
						Stage	1974	1975	2
						Storage	1977	1977	1
						Temp-H2O	1970	1994	25
Clear Creek	11310500 11372000	B0-2535 A3-6130	380355 403048	1210900 1223123	CALAVERAS R NR STOCKTON CA CLEAR C NR IGO CA	Flow	1926	1950	8
						Flow	1941	1994	54
						Stage	1974	1975	2
						Temp-H2O	1965	1979	15
						Flow	1908	1994	87
Cosumnes River	11335000	B1-1150	383001	1210239	COSUMNES R A MICHIGAN BAR CA	Sed. Q-st/d	1963	1970	8
						Stage	1974	1975	2
						Temp-H2O	1966	1979	13
						TSS mg/l	1963	1970	8
						Flow	1941	1994	54
Cottonwood Creek	11376000	A0-3520	402314	1221415	COTTONWOOD C NR COTTONWOOD CA	Sed. Q-st/d	1963	1980	8
						Stage	1974	1975	2
						Temp-H2O	1965	1986	13
						TSS mg/l	1963	1980	8
						Flow	1950	1994	45
Cow Creek	11374000	A4-8110	403019	1221356	COW C NR MILLVILLE CA	Sed. Q-st/d	1978	1978	1
						Stage	1974	1975	2
Deer Creek	11374000	A4-8110	403019	1221356	COW C NR MILLVILLE CA	Temp-H2O	1965	1979	15
						TSS mg/l	1978	1978	1
						Flow	1912	1994	79
						Stage	1974	1992	3
						Flow	1977	1977	1
						Sed. Q-st/d	1977	1977	1
						Temp-H2O	1977	1977	1
Deer Creek	11383500	A4-3110	400051	1215650	DEER C NR VINA CA	TSS mg/l	1977	1977	1
						Flow	1977	1977	1
Deer Creek	11383600	A0-4330	395812	1220048	DEER C A RED BRIDGE NR VINA CA	Flow	1977	1977	1
						Flow	1977	1977	1

Table B-17. Continued

Watershed Name	USGS Station ID	DWR Station ID	Latitude	Longitude	Station Name	Parameters Measured	First Year of Record	Last Year of Record	Years Operated
Elder Creek	11379500	A3-3110	400129	1223031	ELDER C NR PASKENTA CA	Flow	1949	1994	46
						Sed. Q-st/d	1963	1963	1
						Stage	1974	1992	4
						Temp-H2O	1963	1963	1
						TSS mg/l	1963	1963	1
	11380500	A0-3320	400305	1220953	ELDER C A GERBER CA	Flow	1950	1979	23
						Sed. Q-st/d	1977	1979	3
						Temp-H2O	1977	1979	3
						TSS mg/l	1977	1979	3
						Conductivity	1972	1979	4
Feather River	11407000	A0-5191	393113	1213248	FEATHER R A OROVILLE CA	Flow	1902	1994	93
						Sed. Q-st/d	1957	1979	23
						Temp-H2O	1959	1992	33
						TSS mg/l	1957	1979	23
						Flow	1965	1994	30
	11407150	A0-5165	392200	1213846	FEATHER R NR GRIDLEY CA	Sed. Q-st/d	1965	1994	30
						Temp-H2O	1965	1994	22
						TSS mg/l	1965	1994	30
						Flow	1942	1985	42
						Sed. Q-st/d	1979	1980	2
	11425000	A0-5103	385401	1213500	FEATHER RIVER NEAR NICOLAUS CA	Stage	1974	1975	2
						Temp-H2O	1962	1984	18
						TSS mg/l	1979	1980	2
						Flow	1901	1994	93
						Stage	1974	1988	4
Merced River	11270900		373118	1201953	MERCED R BL MERCED FALLS DAM, NR SNELLING CA	Flow	1966	1994	27
						Conductivity	1985	1994	10
						Flow	1941	1994	54
						Stage	1974	1975	2
						Temp-H2O	1985	1994	10
	11271500				MERCED R NR LIVINGSTON CA	Flow	1922	1944	22
						Flow	1929	1994	66
						Stage	1974	1975	2
						Flow	1977	1979	3
						Sed. Q-st/d	1977	1979	3
Mill Creek	11381500	A4-4110	400317	1220123	MILL C NR LOS MOLINOS CA	Temp-H2O	1977	1979	3
						TSS mg/l	1977	1979	3
						Flow	1977	1979	3
						Stage	1974	1975	2
						Temp-H2O	1962	1976	14
	11381595	A0-4421	400244	1220539	MILL C A SHERWOOD BRIDGE NR LOS MOLINOS CA	Flow	1926	1994	69
						Stage	1988	1988	1
						Flow	1950	1967	18
						Flow	1950	1967	18
						Flow	1950	1967	18
Mokelumne River	11323500	B0-2143	381314	1200219	MOKELUMNE R BL CAMANCHE DAM CA	Flow	1905	1994	90
						Stage	1974	1975	2
						Temp-H2O	1962	1976	14
						Flow	1926	1994	69
						Stage	1988	1988	1
Paynes Creek	11377500	A0-4620	401550	1221110	PAYNES C NR RED BLUFF CA	Flow	1950	1967	18
						Flow	1950	1967	18

Table B-17. Continued

Watershed Name	USGS Station ID	DWR Station ID	Latitude	Longitude	Station Name	Parameters Measured	First Year of Record	Last Year of Record	Years Operated					
Sacramento River	11370500	A2-1010	403604	1222636	SACRAMENTO R A KESWICK CA	Conductivity	1981	1984	4					
						Flow	1939	1994	56					
						Stage	1974	1975	2					
						Temp-H2O	1981	1984	4					
	11447500	A0-2100	383512	1213016	SACRAMENTO R A SACRAMENTO CA	Flow	1949	1979	31					
						Sed. Q-st/d	1957	1979	23					
						Stage	1980	1994	13					
						Temp-H2O	1959	1979	21					
	11447650	B9-1850	382720	1213007	SACRAMENTO RIVER AT FREEPORT CALIF	TSS mg/l	1957	1979	23					
						Conductivity	1973	1993	7					
						Flow	1949	1993	45					
						Sed. Q-st/d	1980	1994	15					
San Joaquin River	11274000	B0-7300	372102	1205834	SAN JOAQUIN R NR NEWMAN CA	Temp-H2O	1962	1993	32					
						TSS mg/l	1980	1994	15					
						Conductivity	1986	1993	1					
						Flow	1912	1993	82					
	11290500	B0-7040	373824	1211342	SAN JOAQUIN R AT MAZE RD BDG NR MODESTO CA	Stage	1974	1977	2					
						Temp-H2O	1986	1993	6					
						Conductivity	1985	1989	5					
						Temp-H2O	1985	1989	5					
	11303500	B0-7020	374034	1211551	SAN JOAQUIN RIVER NEAR VERNALIS CALIF	Conductivity	1902	1993	16					
						Flow	1924	1993	65					
						Sed. Q-st/d	1960	1994	34					
						Stage	1975	1975	1					
Stanislaus River	11302000	B3-1130	375106	1203813	STANISLAUS R BL GOODWIN DAM NR KNIGHTS FERRY CAL	Temp-H2O	1959	1993	25					
						TSS mg/l	1960	1994	34					
						Flow	1957	1994	38					
						Temp-H2O	1966	1994	28					
	11302500	B0-3160	374638	1205107	STANISLAUS R AT OAKDALE CALIF	Flow	1896	1994	6					
						Temp-H2O	1985	1994	10					
						Conductivity	1985	1989	5					
						Flow	1941	1993	53					
11303000	B0-3125	374347	1210634	STANISLAUS R A RIPON CA	Stage	1974	1975	2						
					Temp-H2O	1985	1989	5						
					Stony Creek	11388000	A3-1110	394907	1221926	STONY CREEK BL BLACK BUTTE DAM NR ORLAND CALIF	Flow	1955	1994	37
											Stage	1974	1975	2
Temp-H2O	1969	1993	25											
Flow	1941	1973	33											
Thomes Creek	11388500	A0-3120	394325	1220247	STONY CREEK NEAR HAMILTON CITY CALIF	Flow	1978	1981	4					
	11382090	A0-3222	395832	1221328	THOMES C AT RAWSON ROAD BRIDGE NR RICHFIELD	Sed. Q-st/d	1978	1980	3					
						Temp-H2O	1978	1980	3					
						TSS mg/l	1978	1980	3					

Table B-17. Continued

Watershed Name	USGS Station ID	DWR Station ID	Latitude	Longitude	Station Name	Parameters Measured	First Year of Record	Last Year of Record	Years Operated
Tuolumne River	11289650	N/A	373959	1202628	TUOLUMNE RIVER BL LAGRANGE DAM NR LAGRANGE CALIF	Flow	1971	1993	23
						Stage	1974	1977	2
						Temp-H2O	1971	1993	22
	11289651	N/A	373959	1202628	COMB FLOW TUOLUMNE R + MODESTO CN + TURLOCK CA	Flow	1971	1994	24
	11289660	N/A	373957	1202740	TUOLUMNE R A LA GRANGE BRIDGE AT LA GRANGE CA	Flow	1991	1994	4
						Stage	1991	1994	4
	11290000	B0-4120	373738	1205911	TUOLUMNE R A MODESTO CA	Conductivity	1985	1993	9
						Flow	1895	1993	57
						Stage	1974	1977	2
						Temp-H2O	1965	1993	24
						Flow	1942	1994	53
Yuba River	11418000	A6-1408	391407	1211623	YUBA R BL ENGLEBRIGHT DAM NR SMARTVILLE CALIF	Stage	1974	1988	3
						Temp-H2O	1973	1979	7
						Flow	1936	1994	59
	11418500	A6-1250	391328	1211603	DEER C NR SMARTVILLE CA	Sed. Q-st/d	1974	1979	6
						Stage	1974	1989	3
						Temp-H2O	1974	1979	6
						TSS mg/l	1974	1979	6
						Flow	1944	1994	51
	11421000	A0-6150	391033	1213126	YUBA RIVER NEAR MARYSVILLE CALIF	Stage	1974	1988	3
						Temp-H2O	1965	1994	17
						Flow	1944	1957	14
	11421500	A0-6120	390840	1213435	YUBA R AT MARYSVILLE CALIF	Temp-H2O	1964	1970	4
						Flow	1990	1994	5
	11423800	N/A	390230	1211952	BEAR R F REL BL CAMP FAR WEST RES NR WHEATLAND C	Flow	1990	1994	5

# **Correlation Analyses of Chinook Salmon Escapements by Watershed, 1967-1991**

## **Appendix C. Correlation Analysis of Chinook Salmon Escapements by Watershed, 1967-1991**

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### **INTRODUCTION**

Monitoring chinook salmon populations to determine the success of the AFRP in meeting systemwide and stream-specific chinook salmon population goals requires that monitoring programs be established on a large number of streams throughout the Central Valley. However, funding constraints may make it impossible to implement long-term monitoring programs for chinook salmon on every target stream. Consequently, a hierarchical approach that focuses monitoring efforts on high-priority streams (i.e., those that make the largest contributions to total salmon production) and uses a subsampling approach on other streams was proposed in the Conceptual Plan (see Chapter 5). The use of indicator streams was proposed as one means of reducing the extent of chinook salmon monitoring without significantly affecting the ability to accurately evaluate abundance trends on a stream-specific basis.

An effective indicator stream is one that can be used to assess trends in salmon abundance in another stream or in several streams within the same geographic area. Therefore, an indicator stream should generally be representative of changes in salmon abundance in other streams on a long-term basis. To identify potential indicator streams, we examined historical (1967-1991) relationships among annual chinook salmon spawner abundance estimates for all Central Valley streams for which baseline records are available. Potential indicator streams were selected based on how closely changes in annual escapement reflected changes in annual escapement in another stream or set of streams during the baseline period. Additionally, factors that may have resulted in the observed relationships and that may affect the utility of a given stream as an indicator stream in the future are briefly discussed.

### **METHODS**

To assess the strength of the historical relationships between spawning escapements of individual streams, Pearson correlation coefficients were calculated for all possible pairwise combinations of streams and hatcheries for which annual escapement estimates were available for the 1967-1991 period. Sufficient records were available for fall- and spring-run chinook salmon to permit separate analyses for these two races. All correlations significant at the 0.05 probability level were plotted to determine the nature of the relationships and the presence of outliers. Years with no spawning escapement estimates for one or both paired streams were excluded from the analysis. We

limited our selection of potential indicator streams to those with annual chinook salmon runs that have historically exhibited strong, statistically significant positive correlations. The geographic proximity of these streams was also considered because salmon runs in adjacent streams are most likely to be influenced similarly by environmental factors and thereby maintain their relationship with one another.

## RESULTS AND DISCUSSION

Tables C-1 and C-2 present the computed correlation coefficients, sample size, and significance determinations for all pairwise combinations of streams and hatcheries supporting fall- and spring-run chinook salmon, respectively.

Among upper Sacramento River tributaries, strong positive correlations were found between fall-run chinook salmon escapement in Cow and Cottonwood creeks, fall-run chinook salmon spawning escapement in Paynes Creek and several miscellaneous creeks, and spring-run chinook salmon escapement in Mill and Deer creeks (Figures C-1, C-2, and C-3, respectively).

Cow and Cottonwood creeks drain opposite sides of the Sacramento Valley (west and east, respectively) but their confluences with the Sacramento River are relatively close. Perhaps one of the most important characteristics of these watersheds is that they are both upstream of Red Bluff Diversion Dam (RBDD). This suggests that RBDD may have influenced these runs similarly since the dam started operating in the late 1960s. DFG (1995) identified Cow Creek as a high-priority stream for spawner escapement monitoring and Cottonwood Creek as a medium-priority stream. Therefore, Cow Creek may be an appropriate choice for an indicator stream.

Of particular interest to CAMP is the relationship between fall-run chinook salmon spawning escapement in Paynes Creek and the combined escapement estimates from several miscellaneous creeks in the upper Sacramento River, including Spring Gulch, China Gulch, Olney Creek, Ash Creek, Stillwater Creek, and Inks Creek. This correlation suggests that Paynes Creek may provide a reliable index of overall abundance in these creeks. DFG (1995) identified Paynes Creek as a medium-priority stream for spawner escapement monitoring but did not include any of the miscellaneous creeks in its list of monitoring needs. Caution should be exercised in evaluating the utility of Paynes Creek as an indicator stream because it is possible that the relationship between Paynes Creek and the miscellaneous creeks is driven by only a few, or possibly only one, of the miscellaneous streams. Additionally, estimates for some streams may not be totally independent if, for example, expansion factors developed from one stream were applied in developing estimates on other streams. It is recommended that these possibilities be examined before indicator streams are established.

Spring-run chinook escapement in Deer and Mill creeks was highly correlated during the baseline period. Both streams are largely unregulated and are located in adjacent watersheds draining the east side of the Sacramento Valley. Additionally, both support wild chinook salmon populations and have been subjected to a relatively low degree of anthropogenic activity. Hence, populations of spring-run chinook salmon in Deer and Mill creeks may be responding to similar environmental

conditions. DFG (1995) identified both Deer and Mill creeks as high-priority streams for spawner escapement monitoring, so there may be no need to establish one or the other as an indicator stream if independent estimates are continued.

A moderately strong positive correlation was found between fall-run chinook salmon spawning escapements in the Tuolumne and Stanislaus rivers (Figure C-4). Both streams are regulated and are located in adjacent watersheds draining the east side of the San Joaquin Valley. Unlike the Merced River, these two tributaries also lack major hatcheries. A general positive relationship between spring flows in the San Joaquin River and total adult returns 3 years later (California Department of Fish and Game 1992) indicates that tributary runs of fall-run chinook salmon are responding similarly to annual variation in tributary, mainstem, and Delta flow conditions during the spring outmigration of juveniles. Like Deer and Mill creeks, however, DFG (1995) indicated the need to continue independent monitoring of salmon populations in the Stanislaus, Tuolumne, and Merced rivers.

Of course, the possibility exists that the observed relationships presented in Figures C-1 through C-4 may change in the future as a result of the types and timing of restoration actions implemented on these streams, as well as factors beyond the control of the CVPIA. Therefore, periodic estimation of annual spawning escapement in non-indicator streams is still warranted on a less-frequent basis to verify the persistence of these relationships into the future.

Table C-1. Pearson Correlation Coefficients for Pairwise Combinations of 1967-1991 Fall-run Chinook Salmon Escapement Estimates for Target Watersheds

	Sacramento River	Clear Creek	Cow Creek	Cottonwood Creek	Battle Creek	Paynes Creek	Antelope Creek	Mill Creek	Deer Creek	Miscellaneous Creeks	Butte Creek	Feather River	Yuba River	American River	Stanislaus River	Tuolumne River	Merced River	Cosumnes River	Mokelumne River
Sacramento River		-0.26 N=16 p=.329	0.55 N=12 p=.063	0.45 N=17 p=.067	0.11 N=25 p=.617	0.54 N=9 p=.131	-0.34 N=19 p=.149	0.06 N=24 p=.782	0.08 N=23 p=.721	0.42 N=20 p=.062	-0.13 N=10 p=.713	0.14 N=25 p=.501	-0.23 N=25 p=.265	0.20 N=25 p=.338	0.42 N=24 p=.043	0.45 N=23 p=.025	-0.10 N=25 p=.649	0.44 N=17 p=.074	-0.12 N=25 p=.570
Clear Creek	-0.26 N=16 p=.329		-0.25 N=12 p=.436	-0.11 N=16 p=.676	0.66 N=16 p=.025	-0.20 N=8 p=.641	0.18 N=12 p=.574	0.41 N=15 p=.124	0.22 N=14 p=.440	0.02 N=13 p=.943	-0.07 N=5 p=.905	0.23 N=16 p=.384	-0.17 N=16 p=.522	0.01 N=16 p=.962	0.17 N=15 p=.535	-0.02 N=16 p=.942	0.47 N=16 p=.065	-0.19 N=8 p=.657	0.03 N=16 p=.928
Cow Creek	0.55 N=12 p=.063	-0.25 N=12 p=.436		0.87 N=12 p=.000	-0.34 N=12 p=.280	0.88 N=7 p=.000	0.26 N=9 p=.506	-0.14 N=11 p=.685	0.16 N=10 p=.657	0.60 N=10 p=.065	0.95 N=4 p=.048	-0.21 N=12 p=.521	-0.35 N=12 p=.259	0.21 N=12 p=.514	0.17 N=12 p=.598	0.27 N=12 p=.402	-0.25 N=12 p=.437	0.68 N=6 p=.139	-0.15 N=12 p=.651
Cottonwood Creek	0.45 N=17 p=.067	-0.11 N=16 p=.676	0.87 N=12 p=.000		-0.34 N=17 p=.178	0.89 N=9 p=.001	0.09 N=13 p=.764	-0.15 N=16 p=.575	0.18 N=15 p=.526	0.54 N=14 p=.048	0.48 N=6 p=.331	-0.18 N=17 p=.497	-0.30 N=17 p=.237	0.19 N=17 p=.456	0.03 N=16 p=.917	0.17 N=17 p=.512	-0.21 N=17 p=.430	0.55 N=9 p=.127	-0.18 N=17 p=.498
Battle Creek	0.11 N=25 p=.617	0.66 N=16 p=.025	-0.34 N=12 p=.280	-0.34 N=17 p=.178		-0.43 N=9 p=.243	-0.39 N=19 p=.095	0.29 N=24 p=.172	-0.15 N=23 p=.499	-0.30 N=20 p=.195	-0.44 N=10 p=.203	0.20 N=25 p=.342	-0.03 N=25 p=.903	-0.08 N=25 p=.709	0.37 N=24 p=.075	0.14 N=25 p=.512	0.15 N=25 p=.479	-0.23 N=17 p=.384	-0.00 N=25 p=.984
Paynes Creek	0.54 N=9 p=.131	-0.20 N=8 p=.641	0.88 N=7 p=.000	0.88 N=9 p=.001	-0.43 N=9 p=.243		0.32 N=8 p=.433	-0.01 N=9 p=.984	0.46 N=9 p=.212	0.93 N=8 p=.000	0.76 N=4 p=.243	0.09 N=9 p=.817	-0.37 N=9 p=.324	0.51 N=9 p=.163	0.17 N=8 p=.688	0.44 N=9 p=.232	-0.07 N=9 p=.858	0.98 N=1 p=.000	-0.01 N=9 p=.988
Antelope Creek	-0.34 N=19 p=.149	0.18 N=12 p=.574	0.26 N=9 p=.506	0.09 N=13 p=.764	-0.39 N=19 p=.095	0.32 N=8 p=.433		-0.10 N=19 p=.697	0.23 N=19 p=.345	0.19 N=18 p=.458	-0.07 N=9 p=.851	0.23 N=19 p=.337	-0.02 N=19 p=.950	0.23 N=19 p=.341	-0.31 N=18 p=.215	-0.15 N=19 p=.529	-0.07 N=19 p=.782	-0.01 N=14 p=.965	-0.19 N=19 p=.428
Mill Creek	0.06 N=24 p=.782	0.41 N=15 p=.124	-0.14 N=11 p=.685	-0.15 N=18 p=.575	0.29 N=24 p=.172	-0.01 N=9 p=.984	-0.10 N=19 p=.697		0.48 N=23 p=.017	0.04 N=20 p=.853	-0.40 N=10 p=.250	0.13 N=24 p=.554	-0.09 N=24 p=.660	0.12 N=24 p=.584	0.53 N=23 p=.009	0.58 N=24 p=.013	0.73 N=24 p=.000	0.11 N=17 p=.683	0.33 N=24 p=.115
Deer Creek	0.08 N=23 p=.721	0.22 N=14 p=.440	0.16 N=10 p=.657	0.18 N=15 p=.526	-0.15 N=23 p=.499	0.46 N=9 p=.212	0.23 N=19 p=.345	0.48 N=23 p=.017		0.49 N=20 p=.030	-0.09 N=10 p=.804	0.30 N=23 p=.165	0.10 N=23 p=.647	0.81 N=23 p=.002	0.02 N=22 p=.944	0.43 N=23 p=.040	0.41 N=23 p=.055	0.20 N=17 p=.444	0.34 N=23 p=.118
Miscellaneous Creeks	0.42 N=20 p=.062	0.02 N=13 p=.943	0.60 N=10 p=.065	0.54 N=14 p=.048	-0.30 N=20 p=.195	0.93 N=8 p=.000	0.19 N=18 p=.458	0.04 N=20 p=.853	0.48 N=23 p=.017		0.65 N=9 p=.059	0.23 N=20 p=.334	-0.27 N=20 p=.244	0.27 N=20 p=.247	0.00 N=19 p=.988	0.30 N=20 p=.195	-0.09 N=20 p=.692	0.98 N=14 p=.001	-0.10 N=20 p=.684
Butte Creek	-0.13 N=10 p=.713	-0.07 N=5 p=.905	0.95 N=4 p=.048	0.48 N=6 p=.331	-0.44 N=10 p=.203	0.76 N=4 p=.243	-0.07 N=9 p=.851	-0.40 N=10 p=.250	-0.09 N=10 p=.804	0.65 N=9 p=.059		-0.25 N=10 p=.487	-0.23 N=10 p=.518	0.04 N=10 p=.920	-0.23 N=10 p=.523	-0.03 N=10 p=.931	0.25 N=10 p=.480	0.29 N=8 p=.491	0.40 N=10 p=.248
Feather River	0.14 N=25 p=.501	0.23 N=16 p=.384	-0.21 N=12 p=.521	-0.18 N=17 p=.497	0.20 N=25 p=.342	0.09 N=9 p=.817	0.23 N=19 p=.337	0.13 N=24 p=.554	0.30 N=23 p=.165	0.23 N=20 p=.334	-0.25 N=10 p=.487		0.14 N=25 p=.492	0.50 N=25 p=.012	0.18 N=24 p=.410	0.28 N=25 p=.174	0.04 N=25 p=.851	0.17 N=17 p=.503	-0.01 N=25 p=.971
Yuba River	-0.23 N=25 p=.265	-0.17 N=16 p=.522	-0.35 N=12 p=.259	-0.30 N=17 p=.237	-0.03 N=25 p=.903	-0.37 N=9 p=.324	-0.02 N=19 p=.950	-0.09 N=24 p=.660	0.10 N=23 p=.647	-0.27 N=20 p=.244	-0.23 N=10 p=.518			0.32 N=25 p=.120	0.00 N=24 p=.991	-0.05 N=25 p=.813	0.05 N=25 p=.827	-0.33 N=17 p=.190	0.38 N=25 p=.061

Table C-1. Continued

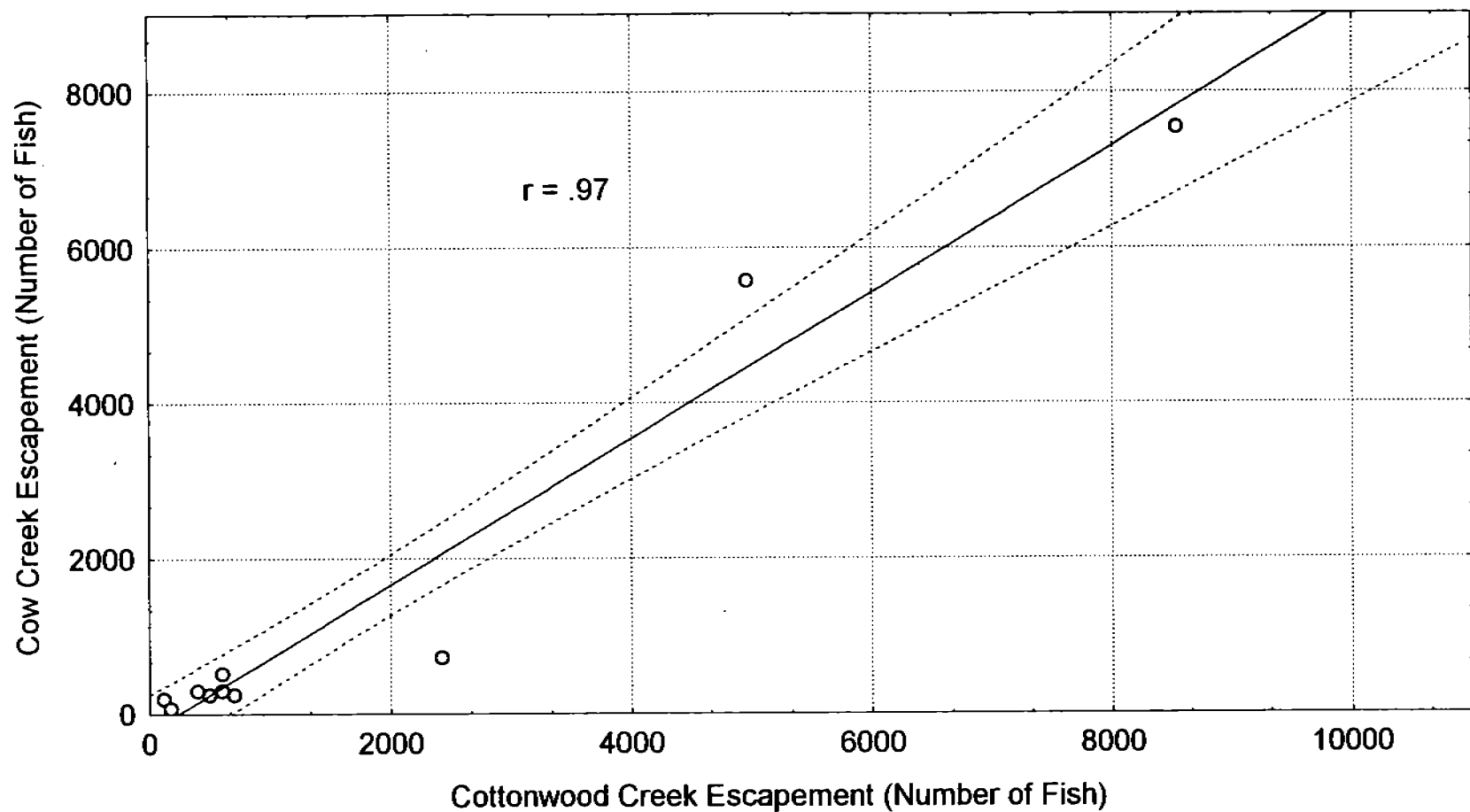
	Sac. River	Clear Creek	Cow Creek	Cottonwd. Creek	Battle Creek	Paynes Creek	Antelope Creek	Mill Creek	Deer Creek	Misc. Creeks	Butte Creek	Feather River	Yuba River	American River	Stanislaus River	Tuolumne River	Merced River	Cosumnes River	Mokelumne River
American River	0.20 N=25 p=.338	0.01 N=16 p=.962	0.21 N=12 p=.514	0.19 N=17 p=.456	-0.08 N=17 p=.709	0.51 N=9 p=.163	0.23 N=19 p=.341	0.12 N=24 p=.584	0.81 N=23 p=.012	0.27 N=20 p=.247	0.04 N=10 p=.920	0.80 N=25 p=.012	0.32 N=25 p=.120		0.04 N=24 p=.843	0.28 N=25 p=.177	0.11 N=25 p=.599	0.08 N=17 p=.764	0.24 N=25 p=.240
Stanislaus River	0.42 N=24 p=.040	0.17 N=15 p=.535	0.17 N=12 p=.596	0.03 N=16 p=.917	0.37 N=24 p=.075	0.17 N=8 p=.688	-0.31 N=18 p=.215	0.82 N=23 p=.019	0.02 N=22 p=.944	0.00 N=19 p=.988	-0.23 N=10 p=.523	0.18 N=24 p=.410	0.00 N=24 p=.991	0.04 N=24 p=.843		0.73 N=24 p=.003	0.29 N=24 p=.174	0.33 N=17 p=.203	0.28 N=24 p=.190
Tuolumne River	0.48 N=28 p=.026	-0.02 N=16 p=.942	0.27 N=12 p=.402	0.17 N=17 p=.512	0.14 N=25 p=.512	0.44 N=9 p=.232	-0.15 N=19 p=.529	0.50 N=24 p=.013	0.43 N=23 p=.040	0.30 N=20 p=.195	-0.03 N=10 p=.931	0.28 N=25 p=.174	-0.05 N=25 p=.813	0.28 N=25 p=.177	0.78 N=24 p=.003		0.47 N=25 p=.018	0.37 N=17 p=.203	0.38 N=25 p=.004
Merced River	-0.10 N=25 p=.649	0.47 N=16 p=.065	-0.25 N=12 p=.437	-0.21 N=17 p=.430	0.15 N=25 p=.479	-0.07 N=9 p=.858	-0.07 N=19 p=.782	0.73 N=24 p=.033	0.41 N=23 p=.055	-0.09 N=20 p=.692	0.25 N=10 p=.480	0.04 N=25 p=.851	0.05 N=25 p=.827	0.11 N=25 p=.599	0.29 N=24 p=.174	0.47 N=25 p=.018		-0.18 N=17 p=.501	0.72 N=25 p=.005
Cosumnes River	0.44 N=17 p=.074	-0.19 N=8 p=.657	0.68 N=8 p=.139	0.55 N=9 p=.127	-0.23 N=17 p=.364	0.38 N=5 p=.038	-0.01 N=14 p=.965	0.11 N=17 p=.683	0.20 N=17 p=.444	0.80 N=14 p=.031	0.29 N=8 p=.491	0.17 N=17 p=.503	-0.33 N=17 p=.190	0.08 N=17 p=.764	0.33 N=203 p=.203	0.37 N=17 p=.141	-0.18 N=17 p=.501		
Mokelumne River	-0.12 N=25 p=.570	0.03 N=16 p=.926	-0.15 N=12 p=.651	-0.18 N=17 p=.498	-0.00 N=25 p=.984	-0.01 N=9 p=.988	-0.19 N=19 p=.428	0.33 N=24 p=.115	0.34 N=23 p=.118	-0.10 N=20 p=.684	0.40 N=10 p=.248	-0.01 N=25 p=.971	0.38 N=25 p=.061	0.24 N=25 p=.240	0.28 N=24 p=.190	0.58 N=25 p=.034	0.72 N=25 p=.003	-0.18 N=17 p=.483	

Note: Highlighted correlations are significant at  $p < 0.05$ .

Table C-2. Pearson Correlation Coefficients for Pairwise Combinations of 1967-1991 Spring-run Chinook Salmon Escapement Estimates for Target Watersheds

	Sacramento River	Mill Creek	Deer Creek	Butte Creek
Sacramento River		-0.20 N=18 p=.421	-0.09 N=18 p=.730	0.18 N=25 p=.389
Mill Creek	-0.20 N=18 p=.421		0.94 N=16 p=.000	0.06 N=18 p=.815
Deer Creek	-0.09 N=18 p=.730	0.94 N=16 p=.000		0.13 N=18 p=.599
Butte Creek	0.18 N=25 p=.389	0.06 N=18 p=.815	0.13 N=18 p=.599	

Note: Highlighted correlations are significant at  $p < 0.05$ .

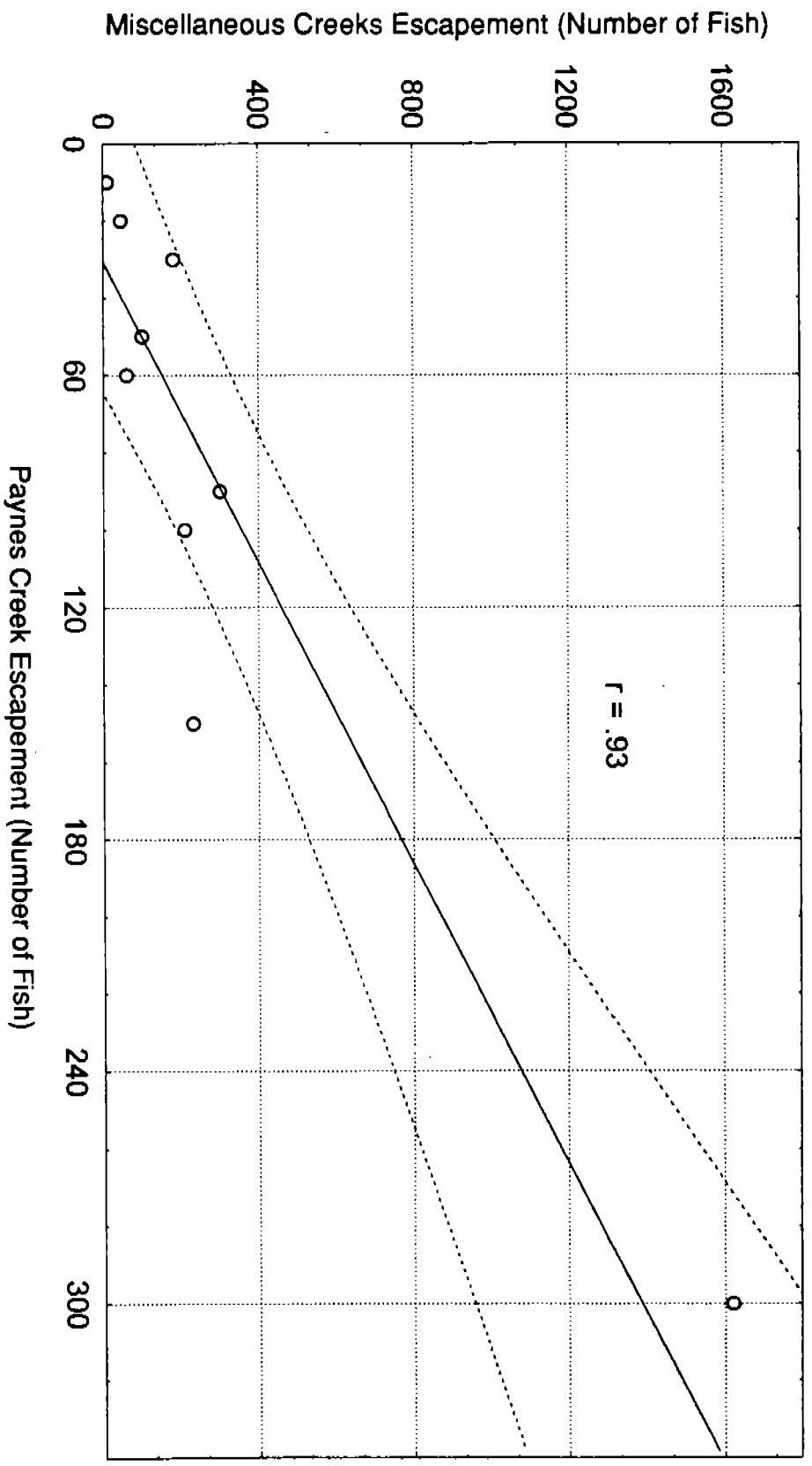


Note: Dashed lines denote 95% confidence limits.



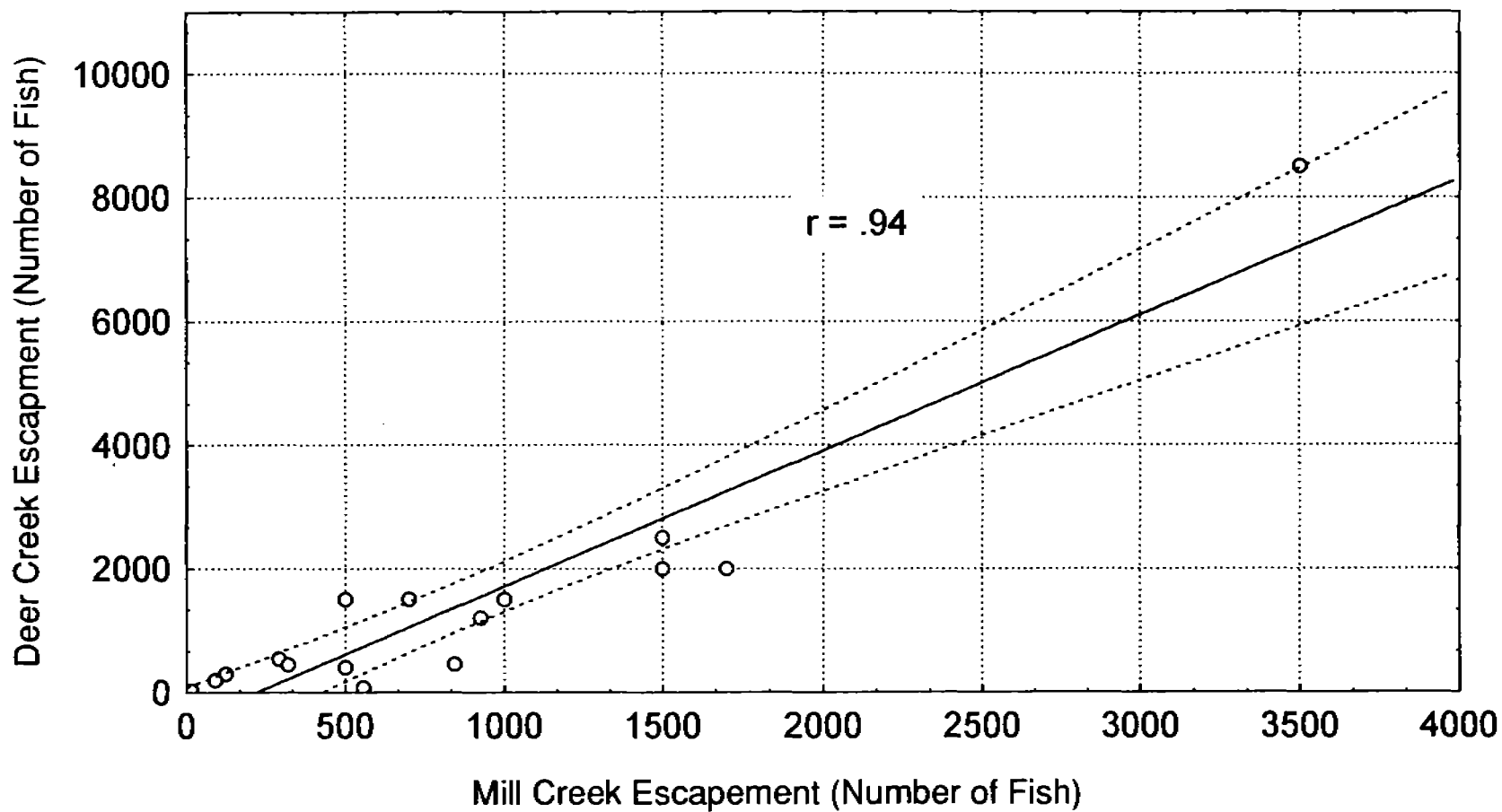
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**Figure C-1**  
**Relationship between Fall-Run Chinook Escapement Estimates**  
**for Cow and Cottonwood Creeks**



Note: Dashed lines denote 95% confidence limits.

**Figure C-2**  
**Relationship between Fall-Run Chinook Escapement Estimates**  
**for Paynes and Miscellaneous Creeks**

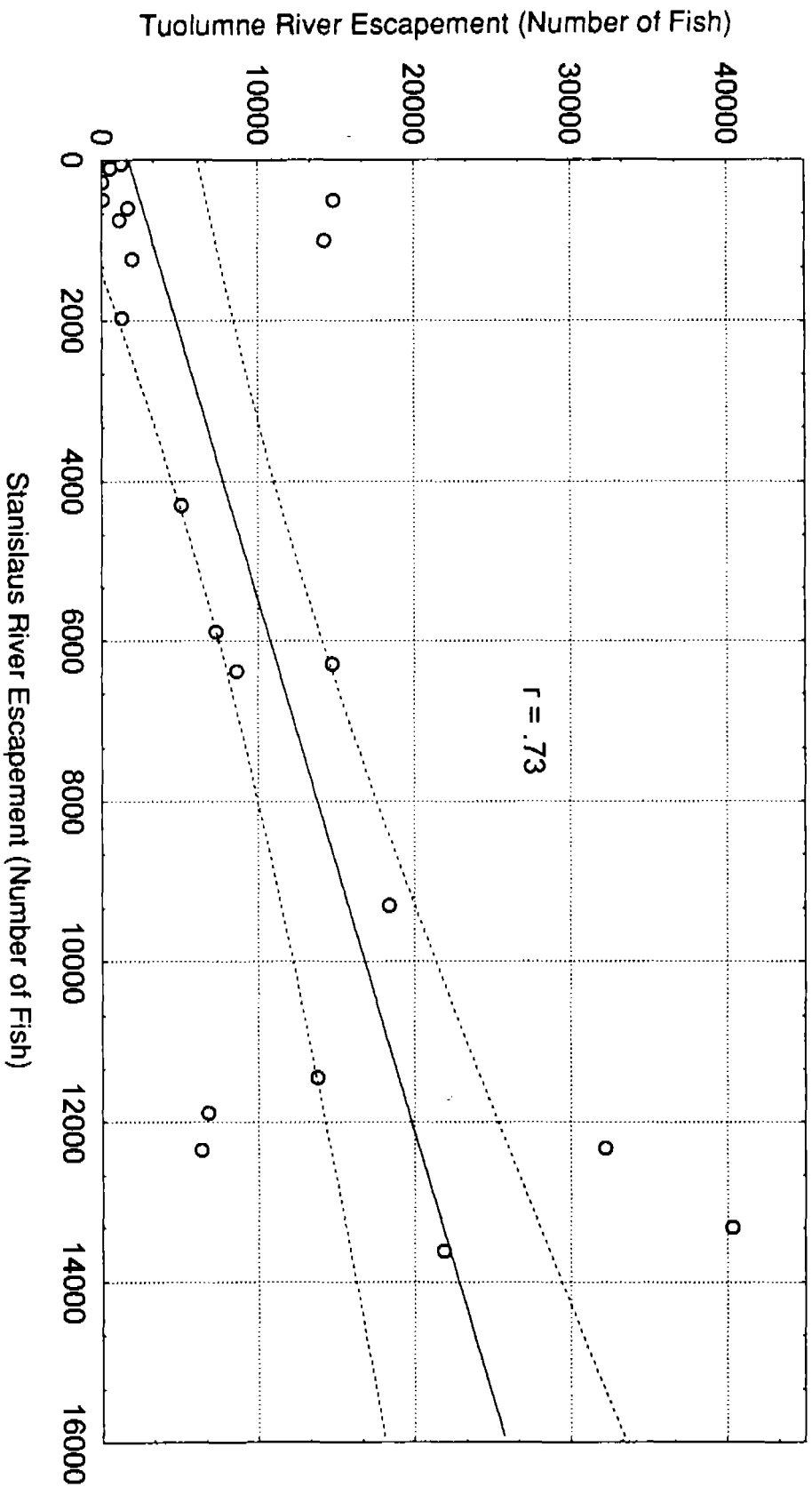


Note: Dashed lines denote 95% confidence limits.



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**Figure C-3**  
**Relationship between Spring-Run Chinook Escapement Estimates**  
**for Mill and Deer Creeks**



Note: Dashed lines denote 95% confidence limits.



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**Figure C-4**  
**Relationship between Fall-Run Chinook Escapement Estimates**  
**for Tuolumne and Stanislaus Rivers**